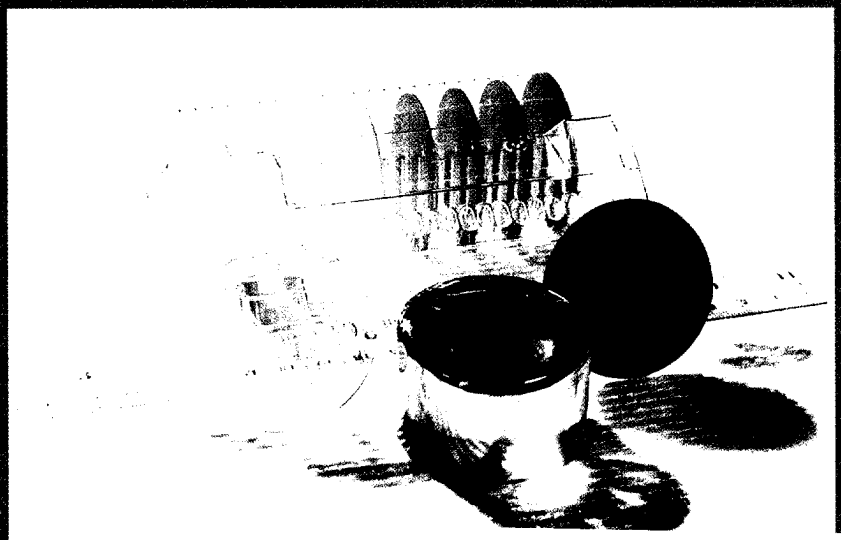
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A Cooperative Technology Transfer Program
with the National Technology Transfer Center

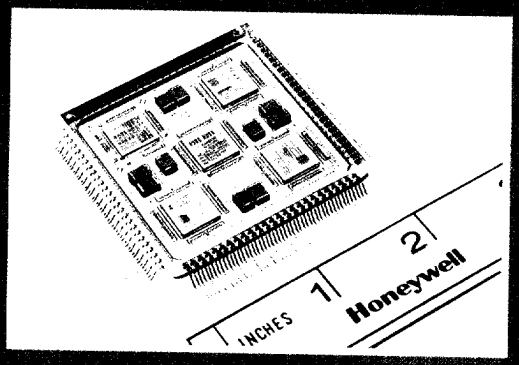
1995 Technology Applications Report

BMDO-funded innovations...

...add value to our Nation's industries. To protect our Nation and our troops from ballistic missile attacks, the Ballistic Missile Defense Organization (BMDO) is developing some of the world's most advanced technology—advances in areas such as lasers, materials, sensors, and energy. And the same technology can give U.S. industries a competitive edge in today's rigorous global economy. It can provide time-saving, money-saving, energy–saving, and even life-saving advances that can reshape the way we live.

For nearly a decade, BMDO's Technology Applications program has assisted small and large businesses, universities, and Federal laboratories in commercializing BMDO-funded technologies. We do this for a lot of good reasons. For one, it is the law. All Federal research and development organizations are directed to actively try to move their R&D into other public and private applications. For another, technology transfer is good for BMDO's sponsors—the nation and the taxpayers—because when BMDO-funded technologies result in commercial products, industry grows, jobs are created, and sometimes whole new businesses are born.

And technology transfer is good for BMDO. When we help our contractors find other uses for their defense work, we strengthen the technology base of the companies we fund. These companies can then more competitively develop innovative technologies to protect against ballistic missiles. This report highlights 50 examples of BMDO-funded technologies that have been or are being commercialized in areas such as communications, energy, manufacturing, and medicine.



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A cooperative effort...

...between the National Technology Transfer Center (NTTC) and BMDO. As a product of this effort, the *1995 Technology Applications Report* exemplifies how Federal agencies can use the expertise and capabilities of the NTTC, which is chartered as a national resource for Federal technology transfer. The end result of the two organizations' cooperation is a strengthened U.S. economy, positioned more competitively in the world marketplace.

The NTTC was established and operates under a cooperative agreement with the National Aeronautics and Space Administration (NASA). Its mission is to facilitate the transfer to, and commercial use by, the U.S. private sector of Federally-sponsored research and technology. NASA has long been associated with, and active in, technology transfer. Administration of NASA's technology transfer initiatives, and the cooperative agreement with the NTTC, resides in NASA's Office of Space Access and Technology.

Technology transfer has been a collateral mission for BMDO ever since its founding in 1983 as the Strategic Defense Initiative Organization. The BMDO Technology Applications program has evolved into a multifaceted technology transfer effort. In 1993, BMDO sought to leverage the NTTC as the single point of entry into Federal technology transfer and asked the NTTC to undertake an innovative and proactive approach to transition BMDO-funded technology to the commercial marketplace.

This document, which is part of the overall cooperative effort between the NTTC and BMDO, is but one example of the synergy between programs with similar missions and goals. Efforts such as this joint, cooperative document will benefit the missions of NASA, NTTC, and BMDO. The final beneficiary will be the U.S. people, through improved, efficient access to advanced technology.

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Accession Number: 6047

Publication Date: Jan 01, 1996

Title: Technology Applications Report 1995

Corporate Author Or Publisher: BMDO, Office of Technology Applications, The Pentagon, Washington, DC 20301-7100

Abstract: This report highlights 50 examples of BMDO-funded technologies that have been or are being commercialized in areas such as communications, energy, manufacturing, and medicine.

Descriptors, Keywords: Technology Application Report Transfer Research Development NTTC Communications Energy Manufacturing Medicine

Pages: 94

Cataloged Date: Jul 12, 1996 Date of Last Use: Jan 22, 1997

Copyrighted or Not: N

Document Type: HC

Number of Copies In Library: 000002

Record ID: 41406

Technology Applications *Report*

Ballistic Missile Defense Organization

FOREWORD

During the Cold War, the significant military and technical might of the Soviet Union was our most serious military concern. The United States grappled with the issue of how to protect our population from an all-out ballistic missile attack. Although each military service had programs in this area, the problem was so immense that it demanded an organized, coordinated approach to defend against ballistic missiles. Out of this "single authority" approach the Strategic Defense Initiative Organization (SDIO) was born. Under SDIO's leadership, federally funded research and development for ballistic missile defense was planned, organized, and executed. That research and development is now coming to fruition.

Now called the Ballistic Missile Defense Organization (BMDO), it leads in the development of military technologies that are maturing into effective, credible systems to counter ballistic missiles. From high-powered, space-based lasers to Earth-based communications systems for command and control, technologies developed by BMDO span a wide spectrum of areas. Each of these steps into advanced technology has enhanced our understanding of everything from basic physics to real-time decision-making technologies for machines so that the Nation can effectively defend itself against future weapons.

BMDO recognized at the outset that their giant strides in defense technologies could be, and should be, used in civilian applications as well. BMDO's Technology Applications program looks at sensors, materials, electronic and photonic devices, and myriad other leading-edge technologies and invites and encourages U.S. industry to use them in the commercial marketplace to increase international competitiveness.

From new lifesaving biomedical devices to educational computer technologies, BMDO's innovations have found their way into the American economy. While we do not rigorously count the results of spinoffs from BMDO technology, we do know from our brief surveys that new products are emerging and new companies are being formed. In addition, technologies originally funded by BMDO are benefiting the American public in diverse areas such as transportation, manufacturing, the environment, and communications.

The *1995 Technology Applications Report* features 50 stories on new ideas, new products, and new companies resulting from BMDO-funded technology. The report is the result of a cooperative relationship between the National Technology Transfer Center (NTTC) and BMDO, who joined forces three years ago to transfer BMDO technology. NTTC's recognized expertise in technology transfer is coupled with BMDO's world-class technologies to help transition them to the marketplace. Look through the report; read the stories; and consider the benefits of advanced technology.

Ismail Akbay
Executive Director, NTTC

Leonard H. Caveny
Director, BMDO Science and Technology

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"New technology needs serial miracles: a discovery based in science, reproducible proof that it works in practice, early investors with more nerve than prudence, an entrepreneur who thrives on chaos and barriers, at least one profitable use, and investors looking for a quick cool billion."

—Carl Nelson, Program Manager
BMDO Small Business Innovation Research

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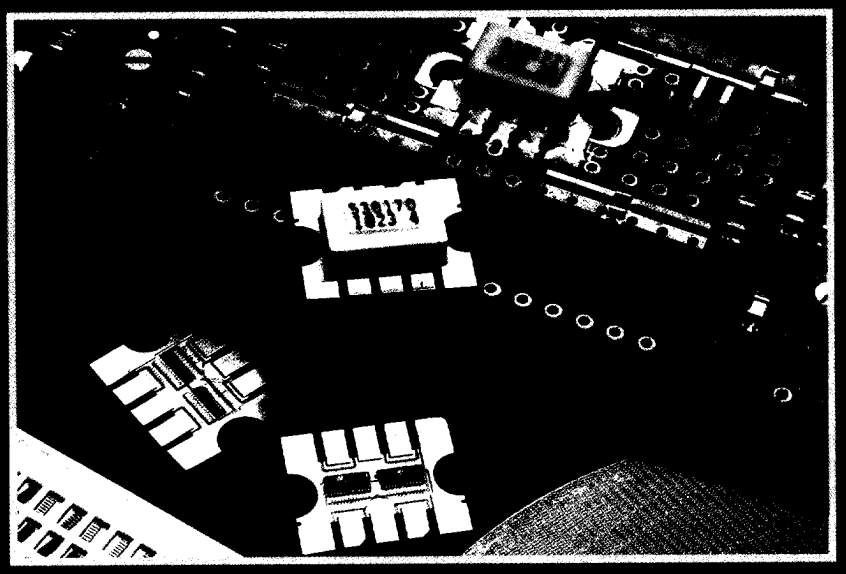
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INTRODUCTION

BMDO's Mission

The Technology Applications program—just a small part...

...of a very big picture. Responsible for designing, developing, and acquiring an integrated missile defense for the future, the Ballistic Missile Defense Organization (BMDO) is dedicated to protecting the United States and its allies from the threat of ballistic missile attacks. It focuses on three major areas highlighted below: theater missile defense, national missile defense, and advanced technology development.



BMDO is upgrading the PATRIOT missile, which is a land-based system designed to intercept aircraft and theater ballistic missiles over a short range. PAC-3 improvements include upgrades to the radar and an improved hit-to-kill missile known as ERINT.

Theater Missile Defense

Protecting U.S. troops and allies...

...from theater missile attacks. BMDO's Theater Missile Defense (TMD) program is designed to protect U.S. forces, allies, and other countries, including areas of vital interest to the United States, from theater missile attacks—attacks from a relatively short range (50 to 500 kilometers). Areas of vital interest include population centers, fixed civilian and military assets, and mobile military units. The program addresses the growing threat from theater ballistic missiles (TBMs), now widely available to many unfriendly countries at a relatively low cost. At the beginning of 1994, there were roughly 8,800 short-range theater ballistic missiles in service in 32 countries. In addition, 30 new types of TBM systems are now being developed.[1]

The TMD program focuses on three areas. For near-term solutions, it is improving several existing air and missile defense systems such as the PATRIOT Guidance Enhanced Missile and the HAWK Air Defense System—an effort that has significantly improved the Nation's defense capabilities since Desert Storm. BMDO also has "core" programs to develop or significantly change systems, such as the new PATRIOT advanced capability called PAC-3, Navy Air Defense, Theater High Altitude Area Defense (THAAD), and Battle Management/Command, Control, Communications, and Intelligence. In addition, BMDO is exploring new concepts for advanced TMD capabilities.



Upgrading the AEGIS (shown above), BMDO is strengthening Navy Air Defense capabilities, which protect naval assets, coastal cities, military forces, and airfields from ballistic missile attack.

National Missile Defense

Protecting the United States...

...from intermediate ballistic missile attacks. Although an immediate ballistic missile attack on the United States is unlikely, the possibility of such an attack will increase as Third World countries develop or acquire simple or perhaps even sophisticated ballistic missiles. Therefore, BMDO is pursuing an R&D program—smaller than its TMD program—to demonstrate the capability of deploying a system to protect the Nation from ballistic missile attacks. In the next 2 to 3 years, the National Missile Defense (NMD) program will demonstrate a ground-based interceptor; a ground-based radar; and a battle management command, control, and communications system that comprise an initial system. While this contingency option would protect the Nation against simple threats, a future, more capable NMD program would also require space-based sensors, such as the Space and Missile Tracking Systems (formerly the Brilliant Eyes program). Such sensors would cue an NMD system against limited attacks by the most advanced ballistic missile systems.

[1] *1995 Report to Congress on Ballistic Missile Defense*, Ballistic Missile Defense Organization, September 1995, p. 2-1.

Advanced Technology Development

Investing in advanced technology...

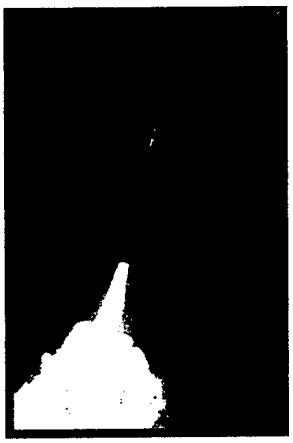
...to counter evolving and proliferating threats. Potential technology requirements, based on reasonable extrapolations of credible countermeasures to future ballistic missile threats, set the pace and direction of BMDO's advanced technology program. The program allows next-generation TMD systems to draw from readily available technology solutions—solutions such as advanced directed energy, sensor, and materials technologies. It then moves those technologies from the laboratory and test facility to usable system components.

The advanced technology program includes the Innovative Science and Technology (IS&T) program, which nurtures high-risk, highly advanced technology. IS&T provides seed funding to promising technologies and transfers them into advanced technology demonstrators.

IS&T also runs the BMDO Small Business Innovation Research (SBIR) program, which funds small businesses to develop far-reaching technology innovations. SBIR projects are funded in two competitive phases. In Phase I, the researcher demonstrates feasibility and develops a design concept. In Phase II, a prototype is built. IS&T also funds the BMDO Small Business Technology Transfer (STTR) project, which encourages cooperative joint research between businesses and nonprofit research institutions, such as academia and government-owned contractor-operated (GOCO) laboratories. The program is structured like the SBIR program.

To transfer BMDO-funded technology to the commercial sector and for other Federal agency use, IS&T also houses BMDO's Technology Applications program—just a small part of a much bigger picture.

BMDO information can be obtained online and through the *1995 Report to Congress on Ballistic Missile Defense.* The on-line address is: http://www.acq.osd.mil/bmdo/bmdolink/html/bmdolink.html.



THAAD, pictured above, is a ground-based interceptor that can intercept theater ballistic missiles over a wider area and at higher altitudes than the PATRIOT.

⊛ Notes From '95

Innovation and diversity...

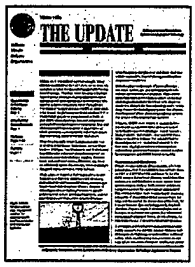
...two ingredients of success. The Technology Applications program recognizes the innovation and diversity of BMDO-funded technology, noting its potential in civilian areas as well—areas such as medicine, transportation, and telecommunications. The same technology that can protect our Nation from ballistic missile attacks and strengthen our national defense can also protect us from disease and strengthen our national economy. And that is why BMDO encourages technology transfer—to maximize our Nation's investment in advanced technology by moving this technology into the commercial sector. But to get there, the Technology Applications program has likewise noted the need for equally innovative, diverse—and proactive—approaches to make industries aware of BMDO-funded technology. The following sections discuss the program's approaches in the areas of Outreach, Technology Applications Reviews, professional society and trade association interaction, and demonstration projects.

Outreach

Spreading the word about innovative technology...

...and finding out what industry needs. The Technology Applications program has established a proactive outreach function to make industries aware of BMDO-funded technology through publications and media relations. Five recent publications highlight innovations in the medical, energy, transportation, law enforcement, and manufacturing arenas.

⊛ *The* Update *newsletter*



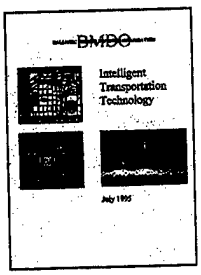
Since 1991, the *Update* has linked businesses with ballistic missile defense technology, opening a window of opportunity to industries and other Federal agencies to make the Nation more competitive in a global economy. With more than 18 issues and 230 stories published to date, this 12-page quarterly newsletter gets the word out about technologies with high commercialization potential in areas such as photonics, microelectronics, materials, and sensors. In turn, the *Update* has facilitated contacts by responding to over 11,000 requests for more information on individual stories. In fact, it responded to more than 3,700 of these requests for the 1995 issues alone.

The Technology Applications program recognizes that the *Update*'s subscribers—people in industry and Government actively interested in technology innovation—are key to the newsletter's effectiveness. Readers' contacts with BMDO-funded organizations often provide the business transactions, impetus, and direction needed to bring BMDO-funded technology to commercial markets. In a Fall 1994 *Update* survey, 17 of the 374 respondents indicated that licenses, joint ventures, venture financing, or product purchases of BMDO-funded technology resulted from the technologies mentioned in the newsletter.

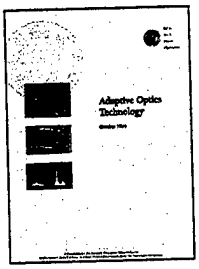
The *Update* also can generate product interest. For example, Sensors Unlimited, mentioned in the newsletter's Summer 1995 edition, anticipates purchases of its uncooled infrared camera on the horizon as a result of *Update* contacts. The *Update* also can leverage visibility for small companies with innovative ideas, as illustrated by 3C Systems, Inc. This company (five employees), which is moving its BMDO-funded electromagnetic technology into automotive airbag applications, was mentioned in the *Update*, attracting the attention of large publications such as Forbes. "The *Update* has given us continued contacts," explained Murray Kornhauser, 3C Systems' president,"Really, the rest is up to us."

What's in the *Update*? The four 1995 issues included articles highlighting medical imaging, intelligent transportation, adaptive optics, and law enforcement as well as short articles on various BMDO technologies covering a wide range of R&D areas. The *Update* has also included articles on subjects of general commercialization interest, such as how to raise venture capital, providing a business perspective in technology transfer. In early 1995, the *Update* won an Award of Excellence from the Society of Technical Communications, Washington, DC, Chapter.

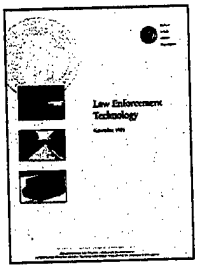
Sometimes there is so much information for a feature story in the newsletter that it warrants its own brief publication. These write-ups give readers a better picture of what BMDO-funded technology has to offer individual markets. The following write-ups were published in 1995.



Intelligent Transportation Technology. Intelligent transportation systems (ITS)—advanced technology to improve the mobility of people and goods—can help meet the challenge of an on-the-go society as it approaches the 21st century. Among other benefits, ITS can reduce accidents, congestion, and environmental damage. This 10-page write-up identifies four areas where BMDO technology can improve ITS: sensors, controls, displays, and communications. It briefly discusses the activities of 20 companies in this area.



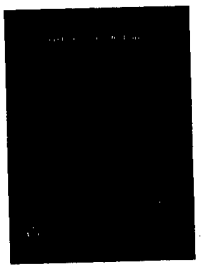
Adaptive Optics Technology. BMDO has funded adaptive optics to measure, and then correct, light that "jitters" through our atmosphere. Astronomers have used the technology for stargazing, over the years, but recently adaptive optics has found uses in manufacturing and medicine. This 8-page write-up highlights the activities of eight BMDO-funded organizations that are pursuing commercial endeavors for their adaptive-optic technologies.



Law Enforcement Technology. BMDO has developed a wealth of technologies, such as communications, information systems, sensors, materials, and optics, that can help police officers with their jobs. This 13-page write-up highlights 19 companies with BMDO-funded technologies that may have uses in law enforcement areas including communications and information management, surveillance and weapons detection, and investigative tools.

• *Applications reports*

Over the years, the Technology Applications program has sometimes focused on areas with high commercialization potential, or on areas where breakthroughs could tremendously benefit the quality of life for millions of Americans. As a result of these ongoing efforts, Outreach has produced detailed reports that highlight these technologies. The reports are designed to make industry aware of the BMDO-funded innovations that either exist now or are on the horizon in these focused areas.

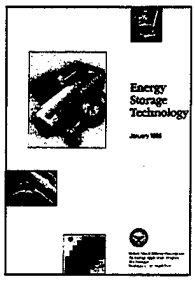


BMDO Technology Applications in Biomedicine. The technologies involved in ballistic missile defense are often similar to those that the medical community needs to identify, diagnose, and attempt to defeat diseases such as cancer. Therefore, the Technology Applications program has produced a report highlighting more than 50 businesses, universities, and Federal laboratories with BMDO technologies that can address medical concerns.

This report has three sections. The first discusses BMDO-funded technologies that can make a strong contribution to existing techniques such as x-ray technology, magnetic resonance imaging, ultrasound, endoscopy, laparoscopy, and photodynamic therapy. This section also includes information about groups involved in less prevalent technologies such as positron emission tomography, single positron emission computer tomography, and particle therapies, to which BMDO-funded developments can make a strong contribution.

The second section discusses emerging medical technologies, including noninvasive infrared sensing; nonlaser, visible light technologies; and computer-aided diagnosis. The third section describes new enabling technologies including materials, readouts, image processing, visualization technologies, and data storage materials.

Energy Storage Technology. Scientists have long sought to lighten society's load by inventing and applying technologies that help power the machines we depend on. From the lever and wedge of our ancestors to the nuclear power stations of today, we have invented many ways to store and supply energy.



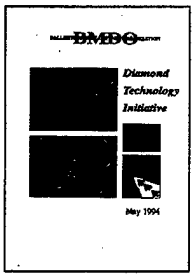
BMDO has power storage needs as well. Highlighting the efforts of 23 BMDO-funded organizations, this 39-page report focuses mainly on one form of storage technology—batteries. BMDO's needs range from batteries that can store and discharge moderate amounts of energy for a year to batteries that must supply a burst of high power over a very short time after lying dormant for years. The report also briefly describes capacitors, flywheels, and other technologies.

o *Press coverage*

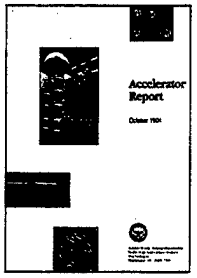
The Technology Applications program successfully worked with the media to make industry aware of BMDO-funded technology and related technology transfers. Program activities have resulted in more than 100 articles about technology commercialization and the program itself in national, local, and trade press. For the second year, these articles have generated more than 400 requests for additional information on the Technology Applications program or specific technologies. Articles have appeared in publications such as *Aviation Week & Space Technology, Business Week, Design News, Mechanical Engineering, Military & Aerospace Electronics, Photonics Spectra, R&D Magazine, Technology Review,* the *San Francisco Examiner,* the *Washington Post, Time, Traffic World, and U.S. News & World Report.*

o *Other publications available from the Technology Applications program*

The Diamond Technology Initiative. Our most requested publication, this 56-page report describes 25 ongoing and recently completed projects funded by BMDO's Diamond Technology Initiative.



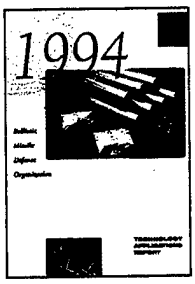
Accelerator Report. The 23-page report describes BMDO-funded accelerator technology and its potential used by medical and environmental industries. Eight BMDO-funded organizations are mentioned.



What's in Store for America's Energy Future. This brochure discusses the potential of superconducting magnetic energy storage, an alternative to traditional methods for storing energy. The efforts of two BMDO-funded companies are highlighted.



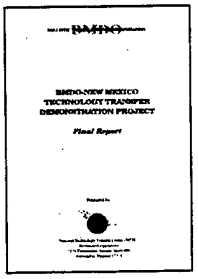
1994 Technology Applications Report. This report, expected to be available online in the near future, highlights 50 1994 BMDO-funded technologies being commercialized.



1993 Technology Applications Report. The report, available in hardcopy, highlights 50 1993 BMDO-funded technologies being commercialized.



The BMDO-New Mexico Technology Transfer Demonstration Project. The 19-page report describes a collaborative effort between representatives from Federal and State governments and a university that may serve as a model for others to follow in commercializing federally funded technology.



For copies of these program publications, contact the National Technology Transfer Center, Washington Operations at the address listed on the inside back cover of this report.

Professional Societies And Trade Associations

Building strong relationships...

...with groups that represent advanced technology users. To facilitate the transition of BMDO technologies to the commercial sector, the Technology Applications program works with a cross-section of professional societies and trade associations. Representative organizations include the American Society of Mechanical Engineers, the Industrial Research Institute, the National Coalition for Advanced Manufacturing, the National Council for Urban Economic Development, the Technical Entrepreneurs and Intrapreneurs Network, the Association of Federal Technology Transfer Executives, and the Technology Transfer Society. BMDO's Technology Applications program has cosponsored projects and meetings with some of these groups, as highlighted below.

• *Workshop on technology transfer in image-guided therapy*

In May 1995, the Technology Applications program cosponsored a workshop in Bethesda, MD, with the National Cancer Institute, NASA, and the Society for Cardiovascular and Interventional Radiologists. The workshop's aim was to identify advanced federally funded technologies to improve image-guided therapies by sharing ideas and information among these diverse groups.

This workshop allowed physicians to air their most pressing technology needs to developers of high technology originally targeted at defense, intelligence, and aerospace uses. For example, a prostate cancer specialist who uses cryoprobes to ablate cancer lesions discussed the need for technology to measure the exact temperature at the probe's end so that she could tell whether or not the cancer cells were being killed. And in turn, the technology developers discussed their latest imaging innovations, which were in compatible areas such as real-time imaging, intraoperative guidance, virtual reality, three-dimensional imaging, and telecommunications—areas where BMDO has invested a significant amount of funding. Focused applications discussed included neurosurgery, head-and-neck surgery, and breast, liver, and prostate cancer.

• *Workshop on making money at technology commercialization*

In late 1994, BMDO cosponsored a workshop called "How to Make Money at Technology Commercialization" with the Technology Transfer Society, KPMG Peat Marwick, and the Technology Utilization Foundation. The workshop provided a forum for leading entrepreneurs and dealmakers to talk about their top money-making tips for successful ventures. It was targeted at potential new business owners and existing firms interested in delving into new ventures. Several BMDO-funded companies spoke at this workshop, which also included presentations from venture capitalists, bankers, intellectual property attorneys, and international trade specialists.

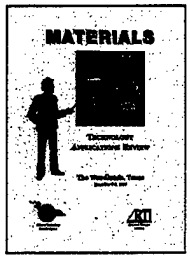
• *Coordination with local economic development agencies*

BMDO also cosponsored a project with the National Council for Urban Economic Development and the Economic Development Administration. A group of expert practitioners visited with economic development agencies and organizations in six cities. The project reviewed regional, State, and local technology-based economic development programs to identify models for other locations. This project gave BMDO a better understanding of State and local programs, which allowed it to leverage State and local activities to promote BMDO-funded technologies. A report released in mid-1995, "Re-engineering Local Economic Development to Integrate Global and Technological Change," discussed numerous case studies about technology transfer programs, including BMDO's.

Technology Applications Reviews

Bringing innovation, capital, and business leadership to the table...

...to identify ways of making BMDO-funded companies more profitable and growth-oriented. Because if businesses are commercially successful and productize their BMDO-funded innovations, then BMDO can later incorporate those products into its large-scale systems. Technology Applications (TA) Reviews use an innovative forum approach to provide commercial advice and information to researchers. In these reviews, a panel of experts assesses and advises researchers on the commercialization strategies for their BMDO-funded technologies. The panel reflects the diversity required to make a business successful, with a wide range of expertise in areas such as venture capital, intellectual property, business formation, and strategic partnerships, all with focuses in different applications areas.



BMDO-funded researchers use this expert advice to shape their businesses, making them more profitable and more commercially driven. The program cannot help write a company's business plan, but researchers can use reviewers' advice to write—or rewrite—their own plan.

Since 1989, roughly 200 inventors from industry and nonprofit organizations, 50 researchers from universities, and 40 researchers from the Government have presented their commercialization strategies in more than 40 TA Reviews. In 1995, the review process focused on areas such as materials, electronics, transportation, and photonics. In previous years reviews have focused, on the environment, sensors, and biomedicine.

• *Success through commercialization reviews*

Over the years, the mentoring process of TA Reviews has helped researchers to focus their work in ways that can make them more successful in a commercial environment. For example, Theseus Research, Inc. (Minneapolis, MN), developed an asynchronous logic for BMDO, which, with the right push, could eliminate the clock function of conventional integrated circuits. It could change a $35 billion industry, enabling the creation of whole new classes of microprocessors and other integrated circuits that are smaller, faster, cheaper to design, and more energy efficient than traditional approaches. But how does a small business change the entire industry?

At the Microelectronics TA Review in September 1994, Ken Wagner, executive vice president of Theseus, learned that to license the technology to a large company he needed to demonstrate a successful product, which in this case, could be done only through strategic alliances. The TA Review process allowed Theseus to establish relationships with various reviewers on the panel, which Wagner describes as essential in guiding the company as it changed. The review and continued contact with the panel has helped the company develop an entirely different business approach—one based on strategic alliances, such as its recent work with Lockheed Martin.

The TA Review process also had an impact on the Trymer Company (Leander, TX) which has a highly innovative energy storage device based on a very old concept—the thermopile (see page 30). The company presented its technology at the Energy TA Review in June 1994, primarily focusing on oil drilling applications; however, on the basis of reviewer input, the small company completely reorganized its efforts, targeting its technology for three separate areas—small-scale power generation, transportation, and large-scale power generation. (Note that none of these focus areas include oil drilling.) The company now has a small-scale generator on the market and is working closely with one of the reviewers to develop another kind of product.

Demonstration Projects

Developing innovative new technology transfer models...

...by working with industry, academia, and Federal, State, and local governments. The Technology Applications program is developing and evaluating new models for transferring technology, as described below.

- *Zones for economic development at Indian reservations*

The Technology Applications program recently sponsored the development of technology transfer models to encourage industrial partnerships with Native American tribes. These "Native American economic development zones" are intended to instill, cultivate, and manufacture advanced technology products on Native American reservations, an effort that can benefit Native Americans, BMDO-funded researchers, and Federal, State, and local economies.

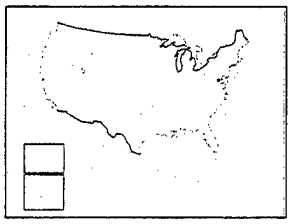
By investing in advanced technology on the reservations, Native Americans can create high-tech jobs for their tribe members and expand their economies into areas that go well beyond gaming casinos and mineral extraction. They can also access a new generation of advanced technologies through reservation-based production facilities or equity investment in growing companies. And the BMDO-funded companies that set up business on the reservations benefit as well because they can realize certain tax incentives and work within simplified regulatory structures.

These models can help companies successfully commercialize the full scope of BMDO-funded technologies, such as materials, software, and lasers. The project has been working with several tribes in Arizona, California, Connecticut, New Mexico, New York, and Nevada. Four potential models have been developed:

- a reservation-based high-technology resource center;
- a reservation-based advanced transportation technology park;
- a market-driven medical device incubator on a Native American reservation; and
- tribal acquisition and reuse of miliary bases as industry R&D and production parks.

- *Partnerships with State and local governments*

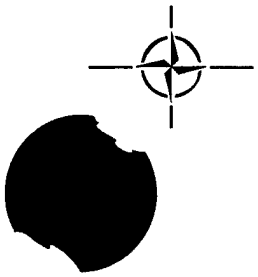
BMDO is cosponsoring the development of models that use State and local economic development service providers to help move its technologies to the marketplace. Staff supporting the Technology Applications program are working with the National Association of State Development Agencies (NASDA). NASDA's members work with thousands of companies each year, many of which have productivity or production problems that may be solved by new technologies. But the companies often have difficulty accessing those technologies because they lack the time and resources for labor intensive research and development commercialization efforts.



NASDA has agreed to tap its network of economic development officials to encourage commercialization of BMDO-funded technologies through a "technology pull" approach. A targeted group of economic development organizations will be introduced to the BMDO program, and that "education" activity will be followed up with a forum designed to introduce BMDO-supported research to businesses.

- *International technology transfer*

BMDO cosponsored a North Atlantic Treaty Organization (NATO) Advanced Study Institute symposium on defense conversion strategies in July 1995 in Pitlochry, Scotland. The Technology Applications program was one model used to illustrate successful examples of the transition of defense technology to the commercial market. The symposium focused on budget realities, social and economic impacts, cultural barriers, and reactions by government and industry as these issues pertain to defense conversion.



1995 Technology Applications Report

Please use this reader response card to order any of the publications mentioned in the opening section of this report or to request more information about any of the technologies featured. Each topic, with its corresponding page number, has been listed below. Please check the appropriate boxes and mail us this card. You may also fax it to (703) 518-8986 or e-mail your requests to leslie@nttc.edu. **Remember to include your name and address**. Our staff will send you the BMDO publications that you request and they will forward your technology information requests to the technology developers.

Your Name and Company Name ( ) Phone Number

Street Address City, State, Zip

Please fold this card and tape it closed. *Do not staple.*

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☐ 11	*Intelligent Transportation Technology (1102)*
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The Technology Applications program can provide more information on innovative technologies.

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Ballistic Missile Defense Organization
c/o National Technology Transfer Center
2121 Eisenhower Avenue, Suite 400
Alexandria, Virginia 22314

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Virtual reality. Because of this new approach to visualization, the way Americans work and play in the year 2000 will be very different from the way they used tools and toys 50 years ago. With this one leap in imagination from the computer age, Americans are now able to experience and actually interact with events and environments that are far away, or even nonexistent.

Advanced technology offers much in this area, allowing, for example, a businessman in California to demonstrate his product to people in New York and note his audiences' facial expressions in real time. It can allow business people to advertise products in three dimensions right on a computer screen or carry their computer screens rolled up underneath their arms like newspapers.

Today's market. Used by everyone from children to chief executive officers, communications and multimedia technologies offer diverse and widespread markets. For example, the percentage of household income spent on telecommunications services is expected to grow significantly from its current 2.1 percent[1] as expanding services include offerings such as multimedia entertainment. The world market for fiber-optic cable is expected to double by 2000; the U. S. share was roughly $3.1 billion in 1993.[2] TV video games accounted for about $3.8 billion of the almost $16.4 billion toy industry in 1994.[3]

Tomorrow's opportunity. BMDO has funded numerous photonics, electronics, computer-related, and even power technologies for tracking and destroying ballistic missiles that may lend themselves to the communications and multimedia industries. The following section highlights seven of these technologies and the companies that are commercializing them.

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[1] *Industry Surveys*, Standard & Poor's, June 1994, p. T-15.

[2] *Industry Surveys*, Standard & Poor's, June 2, 1994, p. T-44.

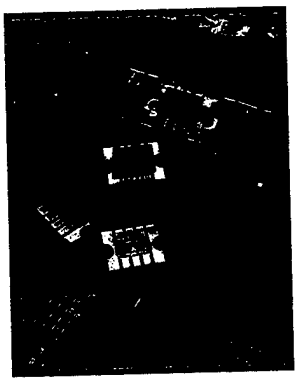
[3] *Industry Surveys*, Standard & Poor's, April 6, 1995, p. L-59.

Counting On Commercial Success

American businesses...

...looking for advanced technology solutions. Many companies have incorporated BMDO-funded technology—which includes some of the most advanced innovations in the world—into their product lines, giving them the competitive edge in an extremely dynamic international marketplace.

- Thirty-nine start-up companies have spun off from Federal laboratories, large companies, or universities to commercialize BMDO-funded technology;
- Roughly 190 new commercial products have resulted from BMDO-funded technologies;
- Twelve BMDO-SBIR companies have gone public, with commercial products available in the marketplace;
- Roughly 385 ventures have been formed on the basis of BMDO-funded technology;
- More than 310 BMDO-sponsored technologies have been patented by the technology developers and at least 210 additional patents are pending; and
- More than 20 cooperative research and development agreements (CRADAs) have been established where BMDO funded technology development at the Federal laboratory before the agreement.



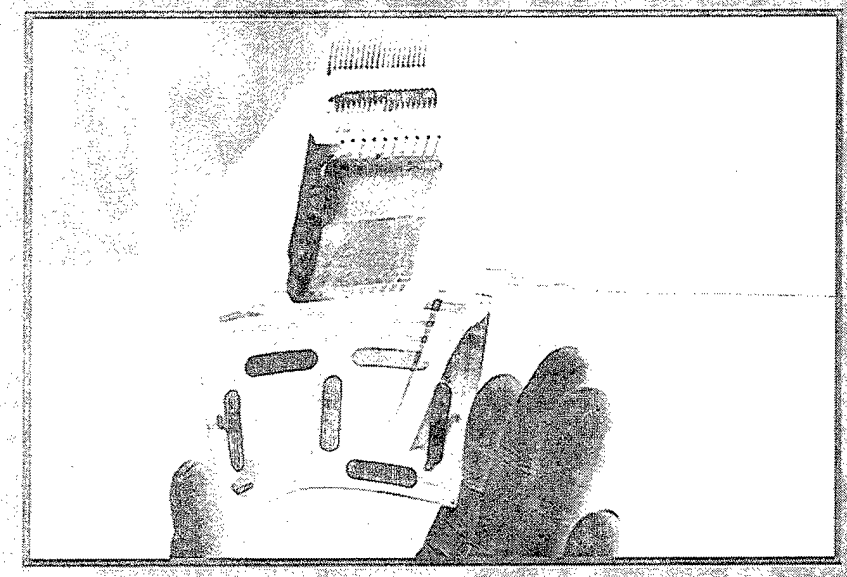
Spectrian Corporation, page 20.

The following sections of this report highlight the top 50 BMDO-funded commercial success stories for 1995. Many of these products that companies, universities, and laboratories are developing are currently on the market; four of the companies have gone public, and five of the companies have spun out from large companies, universities, or laboratories.

NTTC

This report was written and produced by the National Technology Transfer Center, Washington Operations for the Ballistic Missile Defense Organization.

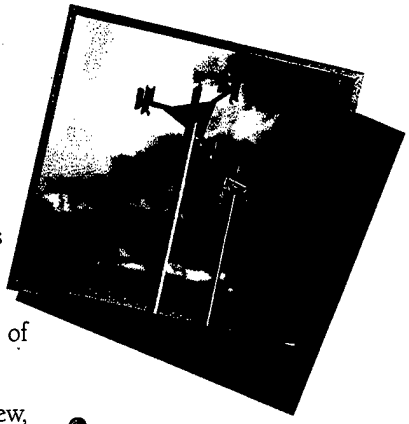
• Editors	Leslie Aitcheson, Lisa Hylton
• Production manager	Lisa Hylton
• Contributing writers	Leslie Aitcheson, Pat Hartary, Ted Lynch, Joan Zimmermann
• Design and layout	Renan Kiper, Lan Crickman
• Advisors	Ralph Albano, Bob Dundervill, Jeff Reynolds, Sally Rood, Tom Tucker, Jean Zettler, Duane Zieg



Uniax Corporation,
page 24

COMMUNICATIONS AND MULTIMEDIA

BMDO-Funded Power R&D Captures Market For Cellular Communications



Spectrian primarily sells its products to large cellular equipment manufacturers.

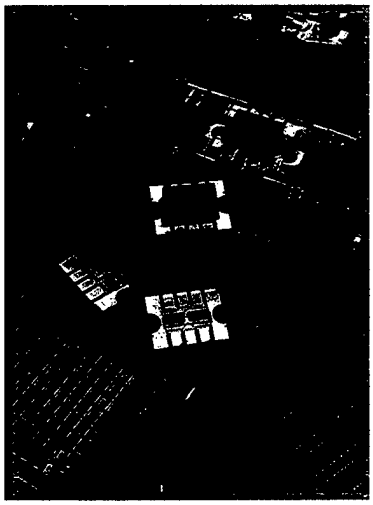
When cellular telephones were introduced in the early 1980s, their financial success came as no surprise; the surprise was in just *how* successful they became. Originally targeting the rich, famous, and very very busy, cellular telephones overcame the obstacles of a then sluggish economy, topping 10 million users in their first decade—figures not projected until the turn of the century.[4]

Capitalizing on this boom in wireless communications, Spectrian Corporation (Mountain View, CA), has undergone the transition from military contractor to commercial supplier, with the help of power technology developed for BMDO's Neutral Particle Beam (NPB) program. Now a major supplier of radio frequency (RF) amplification systems, Spectrian sells its products primarily to large cellular equipment manufacturers, such as Northern Telecom, Ericsson, AT&T Corporation, Motorola, and QUALCOMM.

> Using BMDO-funded R&D for its cellular communications products, Spectrian is capitalizing on the boom in wireless communications.

Spectrian's systems are being used in the base stations of cellular systems; broadband, personal communication services; personal communication networks; and fixed wireless access networks. In 1993 (the most recent year for which data are available), the company accounted for about 15 percent of the quarter-billion-dollar-plus market for cellular base stations. It held an initial public offering in August 1994.

The company's systems can support an array of analog and digital transmission standards and can provide the power levels needed by the base stations that cover both large geographic regions (macrocells) and by those that cover smaller regions (microcells). The main selling point of the company's amplifiers is linearity. Linearity is a measure of the degree to which amplified signals remain within their prescribed band of the electromagnetic spectrum with low distortion or interference from adjacent channels. With greater linear power amplification, base stations can transmit more signals at a given frequency range. This gain in spectrum efficiency means lower capital costs per subscriber and clearer, higher quality transmission.



Spectrian's power transistors and amplifiers, shown above in various stages of production and packaging, provide better linearity; better linearity allows base stations to transmit more signals at a given frequency range, translating to clearer, higher quality transmission.

About The Technology

For the BMDO NPB program, Spectrian designed and manufactured lightweight, reliable, high-power amplifiers for compact particle accelerators. In these accelerators, the amplifiers produce the RF signals used to accelerate and bunch particle beams.

During this work, Spectrian helped spur dramatic progress in the power output of a single RF transistor at specific frequency ranges. A single device developed for this program produced up to 250 watts at 425 megahertz (MHz)—five times better than previously possible. Spectrian's research also cut the cost of solid-state power transistors by a factor of 10. The NPB program later funded the company to build high-power transistors that operate at 850 and 1,700 MHz. The high-peak-power requirements of all these transistors played a big role in improving the linearity of the devices Spectrian sells today.

Building on this technology, Spectrian has developed a technology for producing multicarrier power amplifiers; that is, amplifiers that can dynamically reallocate frequencies so that base stations can follow automotive traffic from cell to cell. The typical multicarrier power amplifier works by combining from 10 to 19 single-carrier power amplifiers in one unit.

[4] *Industry Surveys*, Standard and Poor's, April 1, 1993, p. T-33.

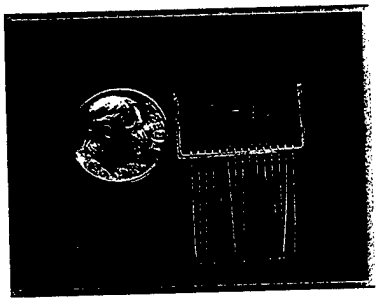
Joint Venture May Break Traffic Bottlenecks On Information Highway

As a result of a recent joint venture, Optical Concepts, Inc. (Lompoc, CA), is entering the commercial marketplace with its vertical cavity surface emitting lasers, or VCSELs (rhymes with pixels)—a move that may meet the growing needs of the telecommunication market. The company's "lasers on a chip" can widen the information highway by allowing more digital traffic to travel over fiber-optic cables while making communications systems simpler and cheaper to manufacture and install. BMDO originally funded this research through an SBIR contract.

By placing thousands of tiny lasers on a single 1-inch chip, researchers at Optical Concepts have developed devices that may reduce the hardware needed to transmit information over fiber-optic cables. These devices will also allow multiple signals to travel simultaneously down a cable, making interactive information services, such as video phones, business conferencing, and distance learning, more affordable and free of bottlenecks. In addition, the company's device has better beam quality than current technology.

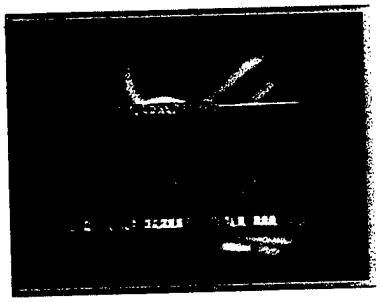
THIS BMDO-FUNDED DEVICE CAN WIDEN THE INFORMATION HIGHWAY BY SIMPLIFYING COMMUNICATIONS SYSTEMS AND MAKING THEM CHEAPER TO MANUFACTURE.

Packaging has been a major cost concern in the traditional processes for manufacturing laser diodes. But since VCSEL chips are smaller and much simpler than conventional diode laser technology, they cost much less to package.



To commercialize its product, Optical Concepts recently signed a marketing agreement with AMP, Inc. (Harrisburg, PA), a Fortune 200 company with a broad business background in electronic packaging and optoelectronics. AMP will market Optical Concepts' VCSEL products and make an equity investment in the company. The capital raised from this deal will allow Optical Concepts to establish the integrated manufacturing facility needed to begin mass-producing VCSEL products.

In the near term, VCSELs can be used in short-distance optical communications such as local area networks. But Optical Concepts is also looking at longer term VCSEL solutions for telecommunications, an area previously plagued with problems associated with limited wavelengths. Signals from earlier VCSELs, which could only operate at near-infrared wavelengths (around 980 nanometers), weakened too quickly for long-distance communications. Optical Concepts recently demonstrated and submitted a patent on the first room-temperature VCSELs operating at 1,550 nanometers—the ideal wavelength for long-haul communications. The company is integrating the lasers in an array specially designed for communications systems.



Optical Concepts has also produced VCSELs that emit blue light. These short-wavelength lasers may be the key to new types of high-density storage devices, since optical storage density increases as wavelength decreases. Blue VCSELs also open the door to applications in high-definition displays and laser printers. Other possible VCSEL uses include medical lasers and spectroscopic imaging.

Above: VCSELs are roughly 20 to 50 times smaller than edge-emitting diode lasers. Pictured above is a VCSEL package produced by Optical Concepts.

Below: VCSELs look like miniature skyscrapers in micrographic images and can be easily stacked side-by-side in one- and two-dimensional arrays.

About The Technology

VCSELs emit laser beams perpendicular to their face surface (hence their name), unlike other diode lasers, which emit light from their edges. At about 10 microns in diameter, they are roughly 20 to 50 times smaller than edge-emitting diode lasers. They look like miniature skyscrapers in micrographic images and can be easily stacked side-by-side in one- and two-dimensional arrays. Researchers have demonstrated better than 90 percent coupling efficiency between VCSELs and fiber optics. Optical Concepts' VCSELs also double the electrical-to-optical efficiency of most competing technology, demonstrating conversion efficiencies of more than 50 percent.

New Amplifiers Improve Fiber Optics

With 60 million kilometers of cable installed worldwide, fiber optics has become an industry standard, forming the backbone of a $5.7 billion global market.[5] Compared with other transmission media, such as copper telephone wires, fiber optics allows telecommunications companies to move more information at a lower cost. And unlike information sent over copper wires, optical digital information can be sent with little worry about the signal scrambling from electromagnetic interference.

But to transfer information over long distances, fiber-optic cables require rather costly electronic regenerators about every 30 to 60 kilometers to boost the signals they carry. Industry could save substantially with low-cost amplifiers to boost signals over longer distances, thereby reducing the number of needed amplifiers.

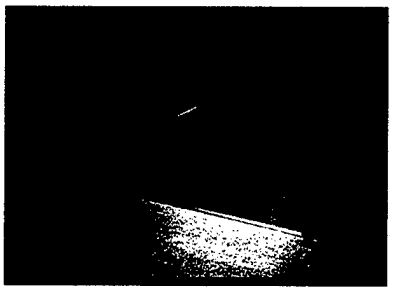
Responding to the call for better transmission, Optigain, Inc. (Peace Dale, RI), is launching four to eight different product lines in active fiber devices, some of which are available now. The company's products are based on BMDO SBIR-funded R&D for erbium-doped fiber amplifiers (EDFAs) and other rare-earth-doped devices. EDFAs can be retrofitted onto existing systems, allowing the industry to upgrade fiber-optic systems quickly and affordably while increasing the distance between amplifiers to about 70 kilometers.

OPTIGAIN'S TECHNOLOGY CAN ALLOW INDUSTRY TO UPGRADE FIBER-OPTIC SYSTEMS QUICKLY AND AFFORDABLY.

In addition, when used with many wavelength division multiplex (WDM) channels, EDFAs can increase bandwidth, allowing 2 to 10 times more information to flow through the communications system. The combination is ideal for broadband communications to support two-way voice, video, and data conveyance.

In the future, Optigain hopes to revolutionize the optoelectronics industry. The company envisions EDFAs, WDMs, and other fiber-optic devices packaged together, in a new technology called integrated fiber circuitry, or IFC. An IFC will be composed of active and passive fiber devices that can be easily interconnected and fabricated using a range of available and developing optical materials. IFCs will yield complex all-optical functions in telecommunications, cable TV, sensing, instrumentation, and optical storage.

Optigain originally developed a low-cost EDFA for BMDO to improve communications capabilities. The BMDO SBIR contract developed EDFAs in the 1,550 nanometer range—the bandwidth for telecommunications that allows data to travel farthest. This research has also contributed to Optigain's efforts in developing lasers and superfluorescent sources. The company has received funding from the Navy and the Air Force in related areas.



Pictured above is Optigain's doped fiber amplifier for the 1,550 nanometer band; it has high output power capabilities of 40 mW.

About The Technology

Optigain, Inc., has developed an optical fiber amplifier used at points of loss in optical systems to intensify the arriving signal. This technology is an example of an active fiber device (AFD) that has broad applications in fiber optics and photonics. In AFDs, silica or heavy metal fluoride glass hosts are doped with one of several rare-earth elements, rendering the fiber optically active when energized with a pumping laser. Rare earths are metals of the lanthanide series of the periodic table (57 through 71). AFDs doped with rare earths such as praseodymium, terbium, and thulium are compatible with the laser propagation modes of current passive fiber devices. By amplifying the fiber-optic beams directly, eliminating an electrical signal conversion step, AFDs reduce power loss and noise in optical systems.

[5] Optical Amplifiers Transform Lightwave Communications...*Photonics Spectra*, January 1995, p. 115.

BMDO-Funded R&D Finds Markets In Amusements, Transportation



The Interactor™ is a vest that, when worn while playing video games, allows players to feel acoustic sensations related to what is happening onscreen.

While attention on multimedia entertainment today seems to be focused on its visual aspects, Aura Systems (El Segundo, CA) is bringing more excitement to the audio side. The company's BMDO-funded high-force actuator (HFA) has been incorporated into products that help players "feel" the sounds.

The company's BMDO-funded electromagnetic R&D can result in acoustic energy or cancel noise and vibration; its uses range from improvements in aircraft, cars, and helicopters to more fun-and-games applications, such as interactive video games and amusement park rides.

Aura has made great strides in commercializing this research, with the Interactor™, a vest that allows video game players to feel acoustic sensations related to what is happening onscreen. The Interactor™ is available in the United States, and Aura has agreements to sell the product in more than 14 foreign countries. The company also won an Innovations '94 Design and Engineering Award from the Electronics Industry Association for the product's development.

AURA SYSTEMS HAS AGREEMENTS TO SELL ITS AWARD-WINNING INTERACTOR™ IN MORE THAN 14 FOREIGN COUNTRIES.

The same technology can add the sense of feeling to theater seat cushions and amusement park rides. HFA technology has already been installed in the Las Vegas Luxor Hotel's Theater of Time. Aura is also involved in a joint venture with InterGroup Corporation to design, assemble, market, and sell entertainment simulator rides. And, on a more musical note, the company has used its technological breakthroughs to make AuraSound™ audio speakers. These speakers have one-sixth the harmonic distortion of conventional speakers and produce no perceptible magnetic interference.

The HFA technology also has some important transportation applications, replacing camshafts and associated valve train components to open and close engine valves. Called electromagnetic valve actuators (EVAs), Aura's technology is expected to increase horsepower and fuel efficiency while lowering emissions compared with standard valve train engines. EVA engines can also use various types of fuels. Aura is testing a 2.3 liter EVA engine and has announced deals with Yamaha, Perkins, and Cummins (some of the world's largest diesel manufacturers) to demonstrate its innovation.

Aura's HFAs can also be used to cancel vibration in helicopters and elevators, as well as in buildings and bridges that are vulnerable to earthquakes or other stress.

About The Technology

Aura's patented HFA is an electromagnetic actuator that can operate at acoustic frequencies (like a loud speaker coil) but produces greater force on impulse than conventional devices. BMDO used the technology for the lightweight exoatmospheric projectile program. HFAs can provide the high forces and long strokes of hydraulic or pneumatic actuators at the speed and precision of voice coil actuators. High-energy permanent magnets are arranged to focus nearly all of their energy into useful work, using nearly 90 percent of the available magnetic energy. Standard voice coil actuators use only about 40 percent. And because the HFAs are completely electromagnetic, no petroleum-based or organic hydraulic fluids are required. This fact, coupled with its shielded design that prevents electromagnetic radiation emissions, makes Aura's HFA technology as environmentally sound as it is commercially attractive.

Flexible Light-Emitting Diodes Result In Licensing Agreement

Sports fans in some seats at stadiums and ballparks may have trouble seeing the electronic scoreboard because of its angle. The lights of the display are not visible when viewed too far from the side. But soon, every fan will have a good view of the scoreboard, because the display will be able to be curved, thanks to Uniax Corporation's (Santa Barbara, CA) bend-like-rubber light-emitting diodes (LEDs).

Because scoreboard displays use thousands of interconnected LEDs with stiff metal electrodes, they must be mounted on flat surfaces. By replacing these electrodes with a processible conducting polymer material, Uniax can manufacture thin sheets of LEDs that can be curled or bent in half without disrupting their light-emitting properties. These highly flexible LED sheets would allow displays to be curved or wrapped around objects. In addition, the new LEDs glow about twice as brightly as a television screen.



This eight-segment polymer electroluminescent display prototype can be flexed during operation and emits bright orange light at 5 volts dc.

Uses for flexible LEDs go far beyond better electronic scoreboards. For example, they may be used to display icons and text in personal telecommunications products, such as pagers, while also reducing power requirements and weight. Eventually they can be used for presentations, allowing business people to roll up high-definition, full-color television displays and carry them under their arm.

> UNIAX IS COMMERCIALIZING A BMDO-FUNDED TECHNOLOGY THAT, AMONG OTHER CAPABILITIES, WILL ALLOW DISPLAYS TO CURVE AROUND OBJECTS.

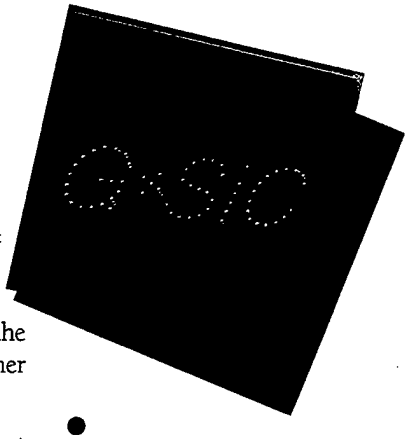
Other applications include windows that automatically control how much sunlight enters a room. LEDs could also be used in transdermal patches to release drug doses on a schedule rather than continuously, like today's patches.

Uniax has licensed to Neste Chemicals (Porvoo, Finland) the core technology, a conducting polymer called polyaniline (PANI), for non-LED applications. PANI is environmentally stable, will not lose its conductivity with typical use, and can be mixed with traditional bulk polymers to improve conductivity. Scaling up to industrial production, Neste Chemicals is using PANI to develop products such as electro-active plastics, coatings, and adhesives and has already demonstrated PANI articles through melt and solution processes.

About The Technology

Previous attempts to make PANI resulted in unmanageable, gelatin-like solutions that could not be processed using traditional melt and solution techniques. Under BMDO SBIR contracts, Uniax Corporation developed cost-effective processing technology that will make it easier to produce PANI in high volumes. By using simple doping techniques, Uniax researchers have been able to increase PANI's processibility. A surface active molecule simultaneously protonates and bonds to PANI polymer chains. As a result, PANI and a variety of polyblends made from PANI become electrically conductive and soluble in several common non-polar or weakly polar organic solvents.

Intellectual Technology Transfer Leads To International Sales



Cree is the largest U.S. producer of blue LEDs, which can be used for displays, as shown above.

In 1987, five graduate students at North Carolina State University realized that their expertise in silicon carbide electronics put them in a unique position to bring a technology with great potential in displays, communications, and high-temperature electronics to the marketplace. The problem was finding the best vehicle for commercialization. Instead of scattering across the country to new positions in industry and academia, these students decided to remain together and form a small company. This way, their concentration of expertise would not break up.

After borrowing money on credit cards, taking out second mortgages, and scraping up investment capital from family and friends, the students formed Cree Research, Inc. (Durham, NC). Two years later, they had their first product on the market—a light-emitting diode (LED) that produces blue light. Such diodes provide the missing ingredient in products designed to display, recognize, or replicate the full color spectrum, including outdoor displays, color recognition sensors, color slide and film scanners, and digital color photographic printers.

Cree Research's success illustrates one of the great values of university-based R&D: lessons learned by students through defense research can create new commercial products.

Some of the early North Carolina State research included BMDO-funded programs in nitride-based semiconductors, materials with properties very similar to silicon carbide. Later, when the students formed Cree, BMDO became one of the company's biggest supporters. The SBIR program awarded the company three R&D contracts and the IS&T program awarded a fourth.

Today, more than 2 years after a 1993 initial public offering, Cree is the world's only significant commercial manufacturer of silicon carbide wafers and the largest U.S. producer of blue LEDs. It sells more than $4 million of these two products annually in the United States, Europe, China, Japan, Korea, and Taiwan. As for the future, Cree recently introduced a brighter blue LED that should greatly expand the technology's market potential, and it has formed several strategic alliances to market its blue LEDs better and to develop new silicon carbide products.

Such success clearly shows one of the great values of university-based research: Students take the lessons they learn with them when they graduate, lessons that sometimes form the basis for new products or help introduce new efficiencies to a business. The full impact of the process, called "intellectual technology transfer," is almost impossible to quantify, since students rarely stay together as they did in the case of Cree.

About The Technology

As a semiconductor material, silicon carbide (SiC) has several properties that make it attractive for devices that provide blue light emission, ultraviolet sensing, nonvolatile computer memory, and high-power, high-frequency, high-temperature operation.

Silicon carbide's most important property is its wide energy bandgap—a property of semiconductors that determines the amount of energy needed to make the material carry current. This wide bandgap (2.8 electron volts) means that heat and other external influences do not readily disrupt the performance of SiC microelectronics, so SiC devices can operate at higher temperatures and higher radiation levels than devices based on silicon and gallium arsenide. SiC can also operate at higher power levels and can emit blue light. Other desirable properties include a high maximum electron velocity (SiC devices can operate at high frequencies), a high thermal conductivity (SiC devices can easily dissipate excess heat), and a high breakdown electric field (SiC devices can operate at high voltage levels).

Several technical barriers to making defect-free, single-crystal SiC wafers had prevented their widespread use. Over the years, Cree has steadily lowered the defect density and cost of its SiC wafers, making the material commercially viable for some uses and nearly so for many others.

Commercialization Of New LEDs May Be True Blue (And Green)

Light-emitting diodes (LEDs) have been available for more than 20 years and are used in everything from electronics indicator lights to sensor devices. But the early devices were limited to the red portion of the visible spectrum; the other colors have been harder to produce, and optimal wavelengths for blue and green have not been available. Large, outdoor color displays can benefit from bright, long-lived, and inexpensive blue and green LEDs. Having red, blue, and green enables LEDs to display all colors, making them useful for advertising, entertainment, and road signs. Optoelectronic managers estimate that the total market for full-color devices may exceed $20 billion annually in the next few years.

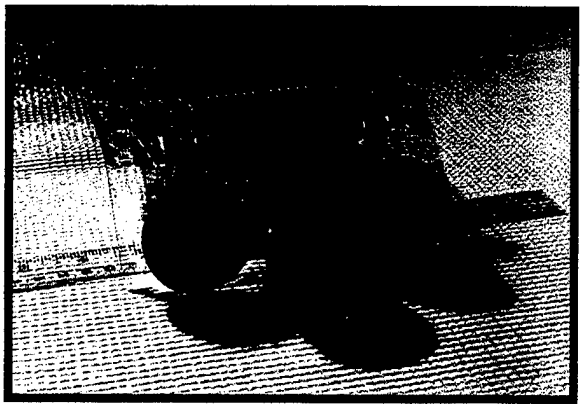
Through a BMDO IS&T contract, North Carolina State University, or NCSU (Raleigh, NC) developed a set of coating technologies for compound semiconductors based on homoepitaxial molecular beam epitaxy (MBE). NCSU used MBE to produce crystalline zinc selenide (ZnSe) thin films, which can be used to make LEDs. The university has licensed the technology to Eagle-Picher (Miami, OK), which has wide experience in the growth of bulk ZnSe. As a result of this partnership, Eagle-Picher is now using NCSU's MBE technology in a $1.75 million award from the National Institute of Standards & Technology Advanced Technology Program for work on blue and green LEDs and lasers. Eagle-Picher plans to manufacture some blue and green LEDs for niche markets. These LEDs have also generated considerable interest from other LED manufacturers.

THANKS TO THIS INDUSTRY/UNIVERSITY PARTNERSHIP, EAGLE-PICHER PLANS TO MANUFACTURE BLUE AND GREEN LEDS FOR NICHE MARKETS.

Blue LEDs are expected to replace red LEDs for applications beyond full-color displays. For example, bright, inexpensive, and long-lived blue and green LEDs could improve the resolution of laser printers. And, on a cybernetic note, blue lasers and LEDs will be useful in advanced computers and networks, which are likely to use optical data storage. These shorter wavelengths offer higher focusing properties and greater inherent information content for optical disks so they can extend their data storage capacity. Blue LEDs also can be used in environmental applications for pollution monitors and in transportation applications for aircraft cockpit displays and automotive instrumentation displays.

About The Technology

These devices are based on compound semiconductor materials composed of precise atomic fractions of type II and type VI elements on the periodic table. Through NCSU's BMDO-funded R&D, Eagle-Picher has developed a bright green LED based on II-VI double heterostructures, such as zinc tellurium selenide (ZnTeSe), grown via homoepitaxial MBE. MBE uses chemical evaporation to grow thin crystalline films with doping profiles that can be carefully controlled. The green LEDs are the brightest green ever reported for a semiconductor material—at least 50 times brighter than commercial gallium phosphide LEDs. They emit light peaked at 512 nanometers and have been shown to operate reliably for up to 675 hours at a current density of 50 amperes per square centimeter.



Pictured above is a collection of NCSU/Eagle-Picher substrates for blue and green LEDs.

NCSU and Eagle-Picher have also developed a blue LED with a crystalline structure similar to the green LED; the difference is in the "active region," which is zinc cadmium selenide instead of ZnTeSe. The blue LED's output is in the microwatt range, compared with that of the brighter green LED, which is in the milliwatt range. However, this LED has generated great excitement because its output is 30 times greater than that of the original blue silicon carbide LEDs. In fact, it produces the brightest blue ever made from II-VI structures.

Reliable, accessible, and affordable electric power is the often-taken-for-granted lifeline of industries, businesses, and homes in the United States. The ability to access it when it is needed is far more than a mere convenience. It significantly affects the Nation's ability to produce competitive products and to perform work in remote locations.

For example, power disruptions can cost manufacturers, such as semiconductor producers, millions of dollars. Utilities, therefore, are pursuing advanced technology that can improve power availability for their customers. One technology being investigated is a coding algorithm to locate power line and equipment failures more accurately so that power lines can be quickly repaired. Recognizing that smart, efficient use of power translates to lower production costs and a stronger bottom line, both utilities and their customers are looking at other energy-related technologies as well.

But assured accessibility—the ability to transport reliable power even to remote locations—is an issue that goes beyond utilities. Consumers and representatives from the health, transportation, and electronics industries are demanding smaller, advanced power sources so that devices such as defibrillators, computers, power tools, and even electric vehicles can be light and small, and operate for long periods of time.

Today's market. Deregulation of the electric power industry is forcing more competitiveness, as large, industrial-based customers begin to choose utilities from which to buy their power. Therefore, utilities are looking at innovative technologies to help them establish a competitive advantage, improve efficiency, and trim costs. According to the National Energy Information Center, U.S. electric utilities had a total of 702,658 megawatts of capacity in 1994. It is anticipated that they will add 42,936 megawatts of capacity over the next 10 years.[1] This expansion will require major investments in technologies that increase energy efficiency and decrease the cost of producing electricity, which will have a positive effect on the United States' ability to compete in the international marketplace.

Tomorrow's opportunity. BMDO has funded many technologies to meet the energy needs of its terrestrial and space missions. Because these technologies are primarily designed for efficient energy generation and storage, they can contribute to commercial energy applications in the utility, transportation, and portable electronics industries. The following section describes the commercial activities of five BMDO-funded companies.

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[1] *Electric Power Annual 1994: Volume I,* Energy Information Administration/Department of Energy, July 1995, p. 1-2.



The Trymer Company,
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ENERGY

Power Source Charges Ahead For Commercial Use



Addressing small-scale power needs, the Trymer Company is developing a cheap, compact 5-kW unit that can be configured to convert heat from almost any type of fuel into usable electricity.

Remote communities of developing countries, which often lack electricity for even the most basic needs, still need small, affordable power sources. In these areas, providing electricity to households is only a pipe dream when even the local clinics cannot get power to refrigerate medications.

Such electricity requirements are not limited to remote locations. For example, in the larger cities of developing countries, homes often must generate their own power during the day (or do without it) because the utilities turn off residential electricity to meet industry peak demands. There are power generators for homes, but they have traditionally been noisy, relatively expensive, and large.

Using BMDO SBIR-funded technology, the Trymer Company is addressing power needs of remote sites and electric vehicles with its unique power technology.

Using technology developed under a BMDO SBIR contract, the Trymer Company (Leander, TX) is developing a cheap, lightweight, compact device for small-scale power needs. The company's 5-kW unit, which costs about $500, is roughly the size and shape of a tall cake pan. It can be configured to convert heat from almost any type of fuel, such as liquid or solid biofuel and compressed natural gas, into usable electricity. The generator can even use concentrated solar energy.

Trymer's innovation is solid-state, so it offers noiseless and vibration-free operation. The unit can provide quality ac or dc power to operate standard appliances such as refrigerators, air conditioners, and U.S.-manufactured power tools. High-tech industries can also use these generators to tap heat from the boilers of buildings to supply power during brief disruptions.

Trymer, however, notes the technology's potential beyond small-scale applications. The company is working with a major U.S. automotive manufacturer to build a 200-pound thermoelectric energy source that is expected to extend the range of an electric vehicle to 600 miles. Trymer has also worked with a major northeast utility, which has developed specifications for an elephant-size 60-MWh magnetic energy storage system. The huge battery-like device will allow utility companies to store some of the electricity they produce at night for use during afternoon peaks, a process called load leveling.

About The Technology

Using a mature technology called the thermopile, Trymer has enhanced this technology's ability to generate electricity from heat. A thermopile is an array of thermocouples—a thermocouple being a pair of dissimilar metallic wires joined at one end. Two thermocouples connected to each other with the two junctions at different temperatures produce a voltage difference often used to measure local temperatures precisely. By connecting many pairs of thermocouples in series, the thermopile can measure very small temperature excursions arising from exposure to infrared radiation. When the thermopile is deliberately exposed to a large temperature excursion, it can generate a large current.

Trymer is taking an integrated circuit approach to this concept to maximize the number of junctions and bring them closer together. The denser thermopile array was formed into a ring with half the junctions sinked to a chill block and the alternate junctions exposed to a heat source. Since each pair of thermocouples is a potential source of current, the circular array produces and sustains internal currents up to 2 million amps. Much of the energy content of the device is in the induced magnetic field of up to 26 Tesla.

Battery Enables Smaller, Lighter Electronics And Cleaner Transportation



GM is targeting Bipolar Technologies' battery for hybrid electric vehicles—vehicles typically powered by a battery and a small internal combustion engine. The photo above is an earlier version of GM's hybrid vehicle, the HX3.

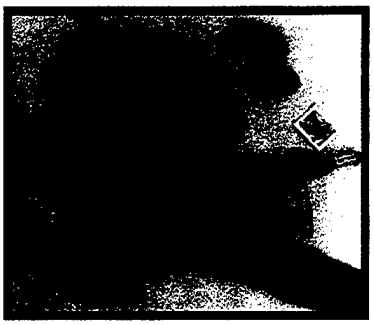
Some owners of new notebook computers have found, after toting their portable devices through airplane terminals, that the devices are surprisingly heavy. While the new, lightweight versions of yesterday's dinosaurs are amazingly light—weighing little more than a hardback novel—the batteries for cordless operation can add pounds to a briefcase. In fact, it is not uncommon for three battery packs (which typically allow a high-end notebook computer to operate for 6 hours) to weigh only slightly less than the computer itself.

Other portable electronic products and systems, such as medical devices and power tools, have much the same problem: Energy needs affect their size and weight, and often, their marketability and usefulness. Under a BMDO SBIR contract, Bipolar Technologies (Provo, UT) has developed a smaller, lighter, and better performing rechargeable battery. Bipolar Technologies' bipolar lead-acid battery distributes energy more efficiently than today's "parallel plate" lead-acid batteries. In fact, it is expected to produce 10 to 1,000 times more power than its lead-acid counterpart for the same energy level. This battery, in some cases, could be as paper-thin as .04 centimeters, enabling consumers, medical personnel, and soldiers to carry much smaller electronic devices that perform as well as or better than current ones.

In pursuit of smaller, lighter batteries, Bipolar Technologies recently struck a deal with General Motors to develop a battery for hybrid electric vehicles.

Larger versions of Bipolar Technologies' battery can be used in hybrid electric vehicles—typically powered by a battery and a small internal combustion engine. Hybrid vehicles have many environmental benefits since they can use a battery to travel emissions-free over short distances, such as through urban areas.

Researchers at Bipolar Technologies recently struck a deal with General Motors Research and Development Center to develop a battery for hybrid electric vehicles—an effort that has led them to a collaboration with Optima Batteries, which has manufacturing capabilities. The U.S. Department of Energy is covering half the cost of this project. The bipolar design for hybrid electric vehicles is a variation of the original BMDO–funded "fast-pulse" battery. It is expected to have 30- to 40-percent higher density than any other battery under development.



Bipolar Technologies is addressing size and performance issues with its battery, pictured above. Compared to similarly sized conventional lead-acid batteries, the bipolar version can increase energy density while quadrupling power density.

Bipolar Technologies' batteries are the result of BMDO IS&T-funded research at Brigham Young University (BYU) and a BMDO SBIR contract at Enyon Corporation. The company has also received a BMDO SBIR contract to develop a polymer carbon composite to enhance the bipolar electrode for advanced railgun and laser applications. Bipolar has filed a patent for the polymer-carbon composite electrode; BYU owns a patent for the basic design.

About The Technology

Batteries with high energy densities allow devices to operate longer on a single charge; high power densities produce larger currents under controlled discharge conditions. The lead-acid battery has traditionally been viewed as a "power battery" because of its combination of stored energy density, electrical current capacity, and rechargeability. Recent research, however, has improved these qualities by implementing new bipolar designs. For example, Bipolar Technologies' lead-acid batteries can increase energy density while quadrupling power density, compared with conventional mass-produced lead-acid batteries. Bipolar's battery is made by stacking thin sheets of an electrically conducting bipolar plate, an active material, and an ionically conducting separator, then sealing the edges and filling the assembly with electrolyte. Performance tests of these cells enable Bipolar to project full-scale battery power levels of 200 kilowatts/kilogram (kW/kg) for a 1-millisecond discharge down to 2 kW/kg for a 5-second discharge.

TOPAZ II PROVES TO BE GEM FOR INTERNATIONAL TECH TRANSFER

A decade ago, many people thought their grandchildren would never live to see the day when former Soviet Union (FSU) and American researchers would do business together—especially in the defense technology area. But once the Iron Curtain came down, paradigms began to shift. U.S. researchers became interested in innovations that Russian scientists had developed, and many Russian scientists wanted to apply their government-funded research to commercial uses.

The first program to successfully shape these types of collaborations in defense technology was the Topaz International Program, funded by BMDO. Six thermionic reactors and the testing facilities for space vehicles were purchased, and technology innovations, especially in the materials area, began to flow into the United States. The FSU, in turn, was able to obtain much-needed capital for its institutes and receive an education in commercializing government-funded R&D.

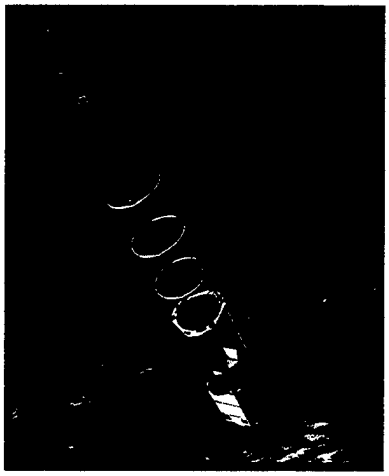
BMDO'S TOPAZ II PROGRAM HAS CREATED MODELS FOR FUTURE BUSINESS DEALS BETWEEN THE UNITED STATES AND THE FORMER SOVIET UNION.

The nations have broken through the bureaucracies and cultural barriers, and learned about each other's business practices, creating new business models that have allowed further cooperation and business deals. In addition, BMDO has saved hundreds of millions of dollars by spinning in existing Russian technology rather than "reinventing the wheel."

BMDO purchased the reactors through a U.S. small business called International Scientific Products, or ISP (San Jose, CA), an affiliate of Space Power, Inc. (same location). This company heads the marketing efforts for a Russian limited-liability joint stock corporation called INERTEK, which was formed around the Topaz II purchase. INERTEK also includes participants from four Topaz II-involved institutes.

The Topaz II acquisition was so successful that a coalition called the United States Industry Coalition (USIC) was formed, adopting many of the lessons learned from the Topaz experience. USIC has now funded roughly 80 collaborations between U.S. Government and industry and the FSU.

Components of the reactor have been cited for several applications. For example, some of the unique materials used for the reactor have grabbed the interest of a major U.S. utility, which is now collaborating with the FSU to increase the lifetime of gas turbine blades. These materials include single-crystal refractory metals and single-crystal ceramics, as well as techniques to bond metal seals to ceramic. Motorola has been investigating Topaz II shipping containers for its IRIDIUM™/℠ satellite communications program. Developed for transporting complete Topaz II systems to the United States via aircraft, these large stainless steel shipping containers have thermal control and inert gas capabilities.

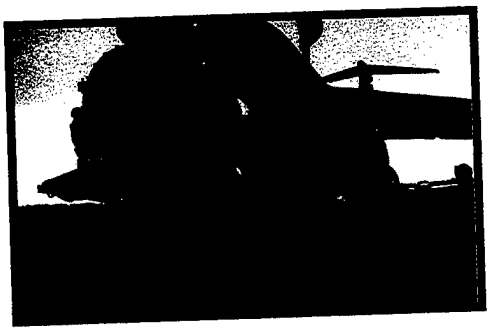


● Pursuing power solutions for space-based missions, BMDO obtained thermionic reactors originally developed by the former Soviet Union.

In addition, the turbomolecular vacuum pump used on the Topaz II test stand can address environmental and manufacturing needs. Able to remove 10,000 liters of material per second, it works like a jet engine in reverse. In a matter of hours this high performance pump can complete a job that would take a competing diffusion pump 2 weeks. The National Center for Manufacturing Sciences has identified 21 other areas where Topaz II technology can be used.

The INERTEK participating institutes (and others) are using working capital from the sale of the reactors to develop non-Topaz-related products, such as spray-on skin for burn victims. A major U.S. health product corporation has shown considerable interest in this topically applied material. The material, which looks and feels like skin, can be sprayed on burns and abrasions, replacing conventional bandages. The institutes also have developed two classes of ozone-friendly refrigerants that do not harm refrigerator parts. Western ozone-friendly refrigerant has typically been incompatible with existing lubricants and sometimes corrodes other refrigerator parts. The refrigerants are undergoing tests for safety and reliability, and will probably be marketed by ISP.

Also, as a result of the formation of INERTEK and stimulated by the Topaz II purchase, a U.S. company is now working with the Russians to build a facility in the FSU that produces cheaper and better boron. In addition to its use in nuclear reactors, boron is essential to manufacture semiconductors and may be valuable in treating cancer patients. Enriched ^{10}B now costs about $3 per gram, but this facility could reduce the cost by two-thirds.



The first of the cargo jets delivering the TOPAZ II thermionic reactors arrived at Kirkland Air Force Base on May 7, 1992.

Who were the players in Topaz II? The initial Topaz reactor was delivered to a consortium of Federal and private organizations including ISP, the Air Force Phillips Laboratory, Sandia National Laboratories, New Mexico Engineering Research Institute (all in Albuquerque, NM), the U.S. Department of Energy, Los Alamos National Laboratory (Los Alamos, NM), and Johns Hopkins University (Laurel, MD). The program also used specialists from the United Kingdom and France. FSU participants were headed by the Kurchatov Institute (Moscow). Other participating FSU institutes include the Central Design Bureau of Machine Building (St. Petersburg), the Scientific Industrial Association "Luch" (Podolsk), and the Scientific Research Institute of Thermal Processes (Moscow). The program currently resides at the Defense Nuclear Agency.

About The Technology

High-tech satellites and space vehicles with long missions are expected to require more power than solar cells can provide. Therefore, BMDO pursued other power solutions, such as space-based nuclear-powered generators. In fact, along with NASA's Jet Propulsion Laboratory and the U.S. Department of Energy, BMDO conducted R&D on some nuclear power space technology in a project called the SP-100 program; however, no near-term, space-qualified solutions were found.

The FSU's institutes (similar to Federal laboratories) successfully developed space-based electric generators, called thermionic reactors, which directly convert heat into electrical energy using nuclear fuel. These reactors are called Topaz II. A version of Topaz, called Topaz I, was used successfully on two FSU satellites.

Negotiations began in 1990, and the Topaz II reactors were delivered to the New Mexico Engineering Research Institute in May 1992. The reactors were then tested using tungsten heaters rather than nuclear fuel. The cost of the initial purchase and test stand assemblies was $13 million.

The innovative testing facilities cost $1 million, while another U.S. space-based nuclear reactor project estimated testing would have cost about $150 million. These large savings are largely due to the group's ability to evaluate the Topaz II power systems using surrogate, electrical tungsten heaters, avoiding the use of nuclear materials.

Design studies for a 40-peak kilowatt (kWe) high-power system have been performed. Under contract with the U.S. Department of Energy, ISP and its sister company, Space Power, Inc., are incorporating Topaz II technology into their SPACE-R reactor concept. The 40-kWe SPACE-R system is expected to weigh less than half and be less than one-tenth the size of an equivalent solar cell system, which typically supplies power levels of about 5 to 6 kWe.

Coding Algorithm Tracks Downed Power Lines



Using the University of Rochester's coding technology, electric utilities can locate their line and equipment failures more accurately so that power can be quickly restored.

During an ice storm, earthquake, or flood, utilities personnel are often left in the dark about which power lines are down. They must wait for customers to call to locate the problem. Such spotty information slows customer service—more important than ever as utilities become increasingly competitive.

The University of Rochester (Rochester, NY) is developing an alarm system that automatically signals a power company whenever a line breaks or fails. In a $300,000 contract with Rochester Gas and Electric Corporation (RG&E), university engineers are building tiny transmitters-on-a-chip that detect power outages by using a BMDO congruential coding technology. BMDO originally funded the technology to increase the number of channels in multiuser radar and spread-spectrum communications.

THE UNIVERSITY OF ROCHESTER IS APPLYING BMDO-FUNDED R&D TO A DEVICE THAT CAN DETECT AND LOCATE POWER LINE FAILURES FOR ROCHESTER GAS AND ELECTRIC.

With the University of Rochester's coding technology, penny-sized transmitters could be built into porcelain insulators that sit on power lines. These transmitters can detect line and equipment failures and then transmit this information to the emergency center of a power distribution network, even in bad weather. With traditional technologies, it is difficult to transmit many signals or discriminate among simultaneously transmitted signals in adverse conditions. By using this coding technology, personnel at RG&E can locate line and equipment failures more accurately within the utility's service territory—without waiting for customers to call. Then they can quickly repair the lines, restoring power and protecting unsuspecting pedestrians from potentially fatal shocks and burns caused by downed power lines.

The University of Rochester also developed the coding technology to detect and classify submarines allowing a torpedo to distinguish between its sonar signal and stray signals, and lock onto its target. The coding technology could provide for even more users in a code division multiple access cellular telephone system than current coding techniques. It could also be used for computer networking systems, sonar, radar, and satellite communications.

About The Technology

Each power line could be outfitted with a transmitter that periodically sends a low-power, coded electrical pulse back into the power grid. Potentially, thousands of signals could be sent back to the utility, but electronic noise within the power lines makes it difficult to find these signals. By recognizing each signal's digital address, or unique code, the coding algorithm can pick signals out of electronic noise and link them with particular transmitters, no matter how many signals are transmitted in the same frequency band. This ability allows a computer at the utility's emergency center to track the codes and, if one vanishes, sound an alert that a line may be down.

Early tests of the alarm system have been successful. Signals sent from transmitters placed on lines at researcher's homes could be detected miles away in their university offices, just by plugging the receiver into a standard wall outlet. More extensive testing will follow if the researchers can bring the cost down from about $500 per unit to well under $200. University researchers are also investigating techniques to simultaneously transmit other types of data signals through existing power lines.

Battery Research May Soon Hit The Highway

Motor vehicles with internal combustion engines are a major source of urban air pollution. In fact, automobiles and trucks account for about 33 percent of the carbon dioxide, 44 percent of nitrogen oxides, and 75 percent of all carbon monoxide emissions in the United States.[2] Electric vehicles are an attractive alternative because they are virtually emissions free. But these vehicles will never be widely accepted until someone develops an affordable, safe, and efficient power source—one that gives vehicles the range and speed needed for practical use.

Arias Research Associates, Inc. (Whittier, CA), has licensed a BMDO-funded sealed bipolar lead-acid battery from Jet Propulsion Laboratory, or JPL, that may be key for electric and hybrid electric vehicle production. With further development, it could provide the range and speed needed by electric vehicles and, unlike many other advanced batteries, also be environmentally friendly. Arias' battery is as safe as the conventional sealed lead-acid versions and can use the same recycling infrastructure. It also uses a blotter-type material that prevents acid from spilling and, because it is sealed, completely eliminates lead emissions.

Using BMDO-funded technology, Arias has been working with a consortium to develop a battery for electric vehicles.

Since licensing the technology from JPL more than 5 years ago, a consortium of sponsors—including the Los Angeles Department of Water and Power, San Diego Gas and Electric, the California Air Resources Board, and the South Coast Air Quality Management District—and several large corporations have supported Arias' work on the electric vehicle battery. The battery is in the product development and demonstration stages; independent testing is being conducted at the Idaho National Engineering Laboratory.



Arias Research Associates' lightweight battery, pictured above, can deliver higher power levels than conventional batteries.

The company has explored smaller scale applications, such as starting, lighting, and ignition functions used by gas-powered cars; uninterruptible power supplies for computers; and electrically heated catalysts to improve the performance of catalytic converters. The battery may also be used by utilities for load-leveling and peak-shaving to meet daily and seasonal spikes in electricity demand.

About The Technology

Bipolar lead-acid batteries can deliver higher power levels than conventional lead-acid batteries because they have more cells spaced closer together. The bipolar plates that connect adjacent cells have a shorter current path and a larger surface area than the connections in conventional cells. These features reduce power loss caused by electrical resistance between cells.

Using proprietary technology that builds on the original BMDO-funded JPL design, Arias has made two major advances toward developing a commercially viable, sealed, bipolar lead-acid battery. First, Arias has developed a bipolar plate that is relatively inexpensive, lightweight, stiff, and resistant to the severe oxidizing environment of the lead-acid battery. Second, the company has developed an advanced formula that has a higher utilization efficiency (i.e., it allows more energy to be extracted from a given weight of material) for the active materials and a longer life.

In laboratory tests, Arias' sealed, bipolar lead-acid battery has demonstrated a specific energy of 47 watt-hours per kilogram and 98 watt-hours per liter (twice the energy of conventional lead-acid electric vehicle batteries and about the same as nickel-cadmium). It has also demonstrated a specific power of 930 watts per kilogram and a life of 3,000 cycles at 50 percent depth of discharge—which means it could last about 10 years in typical usage.

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[2] *Tomorrow's Energy Today*, National Renewable Energy Laboratory, April 1992, p. 8.

Environmental technology helps protect the Nation's most basic resources—air, water, and soil—from pollution. The debris of people's daily personal and business lives, if not kept in check, not only limits the ability to produce and compete, it also threatens quality of life, and sometimes, life itself.

That is why researchers are seeking innovations to enhance the four basic types of environmental-related technology: monitoring, control, remediation, and avoidance. For example, researchers are addressing the need for real-time in situ monitors for stack monitoring so they can address compliance concerns by determining the exact pollution levels coming from specific processes at any given time. They are developing new techniques to treat "untreatable" problems, such as nuclear waste. And they are finding new consumer products, in areas such as refrigeration, to prevent ozone depletion.

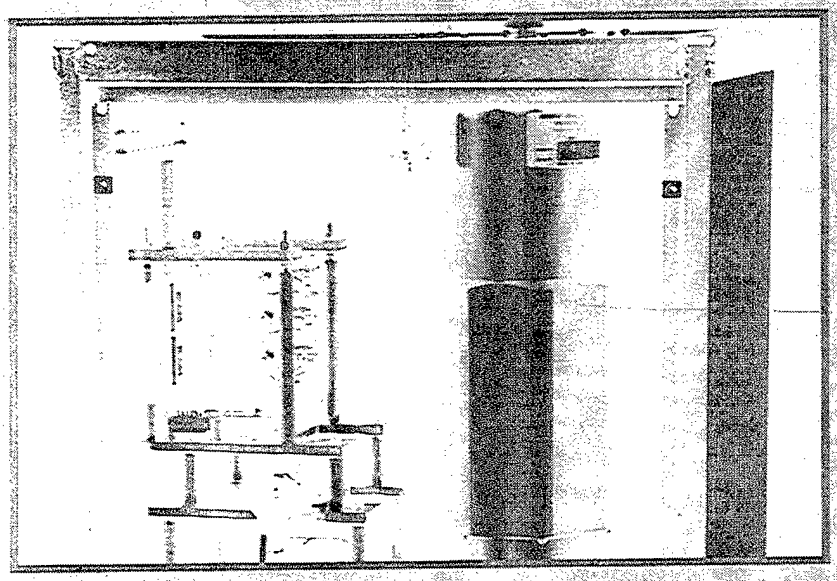
These technologies represent lucrative opportunities for the United States to export products to developing nations. Right now, environmental technology can be cost-effectively incorporated into these countries' new and growing industrial infrastructures, making a positive worldwide impact on environmentally sustainable growth.

Today's market. The environmental equipment industry is relatively young and is being driven by government regulations and growing world concerns about the risks and costs of pollution. Since its technologies are so diverse, purchasers of environmental equipment and "green" (or environmentally benign) technologies include almost everyone—manufacturers, businesses, and consumers. The United States is the world leader in environmental technology products and services, generating $147 billion in related businesses that employ more than 1 million people. The global market for environmental goods and services is about $300 billion and is expected to grow to $400 to $500 billion by the beginning of the next century.[1]

Tomorrow's opportunity. BMDO has funded the development of new sensing, identifying, and controlling technology to counter emerging ballistic missile threats. Many U.S. companies are now finding that some of this technology can help the Nation, as well as other industrialized and developing countries, to solve environmental problems caused by growing economies and populations. The following section describes seven technologies addressing environmental problems in areas such as nuclear waste treatment, toxic gas production, hazardous material detection, and clean alternatives to refrigeration.

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[1] *Bridge to a Sustainable Future: National Environmental Technology Strategy,* National Science & Technology Council, April 1995, p.12.



Physical Sciences Inc.,
page 38

ENVIRONMENTAL TECHNOLOGIES

Early Warning Sensor To Find Hazards In Environment



The oil industry can use PSI's imager to detect and monitor the levels of hydrocarbon and chemical releases.

Government facilities, industries, and commercial businesses often share the same problems in protecting the environment. Leaks from storage tanks, spills from waste handling operations, and release of toxic substances during manufacturing all present cleanup problems that must be dealt with to meet the Nation's growing green standards. The cleanup cost can be exorbitant—estimated at hundreds of billions of dollars for Government sites alone.

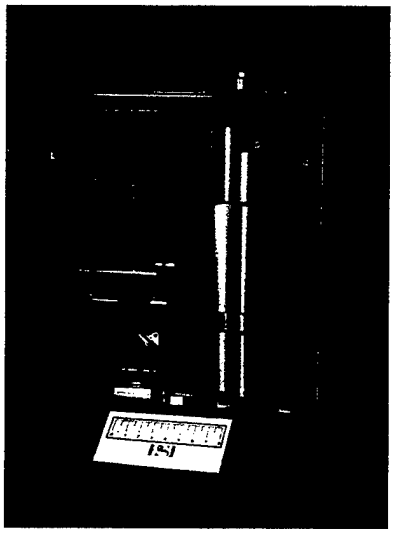
One way to reduce these costs is by developing monitors that crews can easily carry to sites where pollutants can be remotely detected and measured. Such monitors can pinpoint where the real problems, or "hot spots," are and eliminate the need for crews to be on-site at locations chosen for monitoring. They can help the ecosystem and public health—and ensure the safety of the cleanup crews themselves—by identifying the areas where risks are great. They can also save the taxpayers and industries money by eliminating unnecessary cleanup where no risks are posed.

PHYSICAL SCIENCES INC. IS USING BMDO-FUNDED TECHNOLOGY FOR A HANDHELD DEVICE THAT CAN INSTANTLY DETECT LEVELS OF HAZARDOUS COMPOUNDS FOR ENVIRONMENTAL MONITORING.

Addressing these monitoring needs, Physical Sciences Inc., or PSI (Andover, MA), is using BMDO SBIR-funded technology to develop a handheld spectral infrared (IR) imager. This device can almost instantly detect and quantify levels of hazardous volatile organic compounds, such as gasoline, diesel, and jet fuel—substances that make up about 60 percent of defense cleanup sites alone. The imager can make cleanup efforts safer by warning cleanup crews when volatile organic compounds are released.

Industry can also use the imager to track hazardous gas plumes. For example, it can help engineers at petrochemical refineries detect and monitor the levels of hydrocarbon and chemical releases. BOVAR Western Research (Calgary, Canada) has become keenly interested in working with PSI and its subsidiary, Spectrum Diagnostix, Inc., to manufacture IR imaging spectrometers to identify and track smokestack emissions, such as those from waste-to-energy facilities.

PSI's solid-state spectral imager is based on the electronic tunable wavelength filter developed under BMDO to serve as an early-warning sensor for ground-to-air missiles. PSI has received other funding as well. For example, Lockheed Idaho Technologies, Inc., has funded some of the development efforts for environmental applications, awarding PSI a $420,000 contract through the Buried Waste Integrated Demonstration program.



The spectral infrared imager, pictured above, is lightweight, has low power requirements, and has fast switching capabilities. It can detect multiple contaminants in near real time.

About The Technology

PSI has developed a spectral IR imager that is lightweight, has low power requirements, and has fast switching capabilities so that it can detect multiple contaminants in near real time. It allows full spectral coverage in the 3- to 5-micron or 8- to 12-micron atmospheric window and has spectral (10 centimeters^{-1}) and spatial (0.5 milliradian) resolutions high enough to detect a range of chemical compounds against arbitrary backgrounds.

The imager produces a two-dimensional digital image of the scene in multiple wavelengths using a planar IR detector array. PSI purchased the detector arrays from suppliers such as Amber (Goleta, CA), which developed IR focal plane technology with BMDO funding. Fields of view in excess of 15 degrees are possible with high optical throughput.

PSI's spectral imager could replace open path Fourier-transform infrared (FTIR) and laser diode sensors for monitoring. The projected cost of a unit is $50,000 to $125,000, depending on options and support specified. Current FTIR spectral sensors cost between $90,000 and $250,000.

Environmentally Friendly Refrigerators Greet The Commercial Market

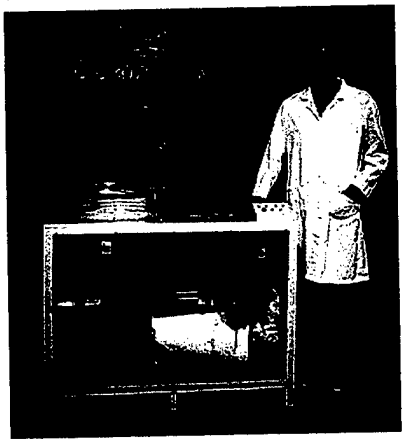
Rocky Research's (Boulder City, NV) work on cooling systems for space-based sensors is providing an unexpected boon for environmentally conscious beachgoers—portable refrigerators and freezers that do not harm the ozone layer of the Earth's atmosphere. The same technology may also cool computer chips and make medical refrigeration appliances lightweight and mobile.

Developed through a BMDO SBIR contract, the relatively cheap and lightweight cooling devices do not use environmentally harmful chlorofluorocarbons, hydrochlorofluorocarbons, and hydrofluorocarbons in their cooling processes. They also have no moving parts and consume little power.

Rocky Research has patented its design and recently signed an agreement with FMC Corporation (Conway, AR) to manufacture complex compound refrigeration and thermal energy storage products. FMC, in turn, has formed FMC Thermal Management Products (same location) to fulfill this agreement, manufacturing the products for both commercial and military applications. Rocky Research has also licensed an option to Igloo Products Corporation (Houston, TX), which will market devices made through the FMC agreement.

ROCKY RESEARCH HAS LICENSED AN OPTION TO IGLOO PRODUCTS, WHICH WILL MARKET PORTABLE REFRIGERATORS MADE WITH BMDO-FUNDED TECHNOLOGY.

These refrigerators have attracted much interest because they are environmentally friendly. For years, engineers have had difficulty in finding alternatives to chemicals such as chlorofluorocarbons for refrigerators and air conditioners. The chemicals used in most cooling processes contribute to the depletion of the ozone layer, which protects the Earth from ultraviolet radiation that can damage the surface cells of both plants and animals. Among the harmful effects of a weaker ozone layer are increased incidences of skin cancer and damaged DNA. Rocky Research's breakthroughs are one step in the right direction.



Through a BMDO SBIR contract, Rocky Research developed a thermally driven heat pump, pictured above, that is environmentally friendly, reliable, and lightweight. The device also has low power requirements.

About The Technology

Reliability, light weight, and low power requirements are essential for space-based systems. Through a Phase II SBIR, Rocky Research's work on the thermally driven heat pump delivers on all three counts, providing cooling systems for space-based sensors as well as numerous commercial applications.

The heat pump uses a solid/fluid mixture consisting of an inorganic metal salt and ammonia vapor; in the evaporation cycle, the salt combines with the vapor to absorb heat and chill a predefined area. The reaction reverses in the condensation cycle and rejects heat exhaust.

With rapid heat and mass transfers, this complex-compound solid-gas sorption system can operate using small, lightweight, and inexpensive equipment. Its simple design and few moving parts reduce the chance of system complications and breakdowns, so that the technology requires little maintenance. The system also has high efficiency and low operating costs thanks to its high refrigerant holding capacity, and it can be easily scaled up to large cooling capacity systems.

BMDO-Funded R&D May Help Reduce The Impact Of Nuclear Waste

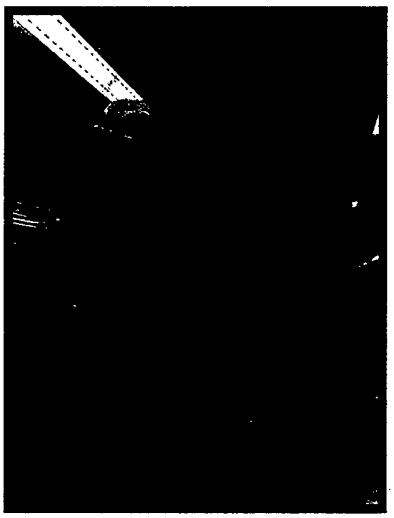
Commercial nuclear waste has become an increasingly tough problem for public utilities, both from a business and an environmental perspective. The 109 commercial nuclear power plants operating in the United States, plus 2 that are no longer in operation, have already generated about 27,000 metric tons of spent fuel that must be safely stored.[2] Within the next 15 years, up to 59,000 tons will have to be dealt with.

What do the utilities do with it? Power plants typically store this waste near their reactors in cooling and storage pools. But these storage centers are now nearing maximum capacity and the utilities are looking for new storage or treatment solutions. The answers are not easy. Facing serious cost, liability, regulatory, and transportation issues, the utilities must deal with substances that will remain radioactive for many thousands of years.

Using technology originally developed under BMDO, researchers at Los Alamos National Laboratory, or LANL, (Los Alamos, NM) are finding ways to use particle beam accelerators to reduce the impact of these wastes. They have developed a design concept called accelerator-driven transmutation technology, or ADTT, to destroy long-lived nuclear waste as well as weapons-grade plutonium. Once fully developed, ADTT could reduce the half-lives of radioactive waste to a few centuries, making it easier to design secure storage facilities. And as an added benefit, ADTT can produce thermal power (just as in a nuclear reactor) for generating electricity—while treating the waste.

Scientists from the former Soviet Union and the United States received a $3 million grant to reduce the hazards of nuclear waste using BMDO-funded R&D.

Receiving international attention, the team has recently been granted $3 million from the International Science and Technology Center (ISTC) to further develop ADTT. ISTC was established in 1992 to support former nuclear weapons scientists from Russia by funding work on civilian projects that reduce the danger of proliferating weapons of mass destruction. Its board of governors includes representatives from the United States, the European Community, and Japan. The Los Alamos project is one of the largest ISTC-funded projects.



Investigating a concept called accelerator-driven transmutation technology (ADTT), researchers at Los Alamos National Laboratory are finding ways to use particle beam accelerators, pictured above, to reduce the impact of nuclear waste.

In the project, Russian researchers will develop hardware, test stands, and databases for accelerator, target, blanket, and separations systems while LANL will provide management support. This effort will provide a new, non-defense mission for more than 200 former weapons scientists from Russia. The scientific fruits of this collaboration should also advance worldwide efforts to reduce the stockpiles of nuclear weapons materials and nuclear wastes.

Commercial spent fuel. One of the two ADTT programs for destroying radioactive material, called accelerator transmutation of waste, or ATW, treats waste from commercial nuclear reactors. ATW uses neutrons to transmute long-lived fission products and actinides in spent commercial reactor fuel, which can remain radioactive for up to a million years. Radioactive isotopes of technetium, iodine, plutonium, neptunium, and americium are among those that could be destroyed by the LANL ATW system.

Weapons-grade plutonium. Accelerator-based conversion, or ABC, is designed to destroy plutonium from weapons and reactor fuel sources. ABC can reduce either weapons-grade plutonium or spent commercial reactor fuel that contains plutonium. In a single cycle, ABC can burn 98 percent of the ^{239}Pu and 90 percent of all plutonium isotopes occurring in weapons-grade plutonium. While this technique does not completely neutralize radioactive material, it does change a significant amount of it into harmless, nonradioactive substances.

[2]Ending the Gridlock on Nuclear Waste Storage...L. Carter; *Issues in Science and Technology,* Fall 1993, p. 74.

Energy production. Researchers at LANL are also finding ways to use accelerator-based concepts for generating electricity, an approach called accelerator-driven energy plants (ADEP). Safer than conventional nuclear power plants, this approach produces significantly less long-lived nuclear waste than conventional nuclear power plants. The laboratory's design concepts rely heavily on particle accelerators. An alternative to conventional nuclear power plants, ADEP transmutes its own long-lived wastes and uses thorium, a more abundant nuclear fuel.

BMDO originally funded neutral particle beam (NPB) R&D at LANL to attack booster or re-entry vehicles. These systems would use an accelerator platform that generates, accelerates, and focuses a beam of ions. The beam is then neutralized and directed at a distant target in space. BMDO chose neutral particle beams because they can propagate for long distances in space without being deflected by the Earth's magnetic field.

About The Technology

LANL has been developing high-performance particle accelerators with BMDO support and under the management of the U.S. Army Space and Strategic Defense Command. The particle beams from these accelerators have a high intensity or brightness and a low emittance. Emittance is a measure of a beam's divergence from its path and relates how little "beam spill" is created. Beam spill is a condition where particles hit the inside of the accelerator, decreasing reliability and operation lifetime, as well as creating radioactive components.



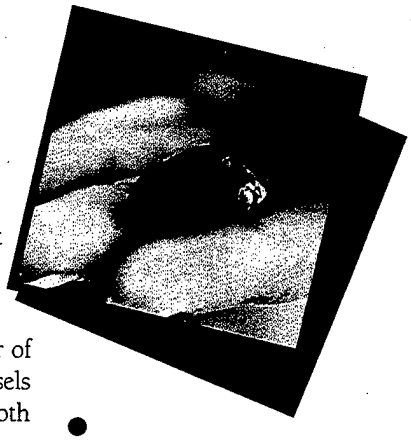
Accelerator-based conversion can burn 98 percent of the ^{239}Pu and 90 percent of all plutonium isotopes occurring in plutonium for weapons. Pictured above is part of a BMDO-funded accelerator contributing to this project.

As a spinoff of this technology, ADTT draws heavily on power source technology developed under BMDO-funded NPB research and development. It uses a blanket assembly to produce neutrons that change radioactive nuclear waste and plutonium to either nonradioactive materials or materials with much shorter half-lives.

In the ABC and ATW programs, accelerators bombard a heavy metal target (such as lead) with an 800- to 1,000-million electron volt, high-energy proton beam. When the proton beam hits the target, it produces an energetic spray of neutrons, about 20 to 30 neutrons per atom in the proton beam. A surrounding blanket of molten salt containing graphite and the nuclear material to be transmuted multiplies these neutrons. This blanket also slows the energy level of the neutrons to increase the probability of transmutation reactions. Materials such as plutonium, waste actinides, or long-lived fission products are continuously introduced into the blanket assembly. Remaining radioactive materials can be separated and reintroduced into the system to further reduce their long-lived radioactivity.

In ADEP, an assembly, which includes a graphite moderator and a fuel such as thorium, surrounds an accelerator-generated source of neutrons. The fuel is embedded in a coolant to obtain the high temperatures and efficiencies needed. The assembly is subcritical and cannot sustain a chain reaction without the accelerator beam.

Tiny Invaders Are Shell Shocked By Researchers' Findings



The zebra mussel has become a costly visitor to the waterways near power plants.

Researchers at Old Dominion University, ODU (Norfolk, VA), have a pulsed power switch that can help solve some of the menacing problems that European zebra mussels are posing for electric utilities in 19 eastern States.

In the mid-1980s, the larvae of these unwanted mollusks hitched a ride in the ballast water of freighters carrying cargo from Europe to Lake St. Clair in the Great Lakes region. Zebra mussels have made themselves at home ever since, and are often compared to the renowned gypsy moth that invaded the eastern United States. Like the gypsy moth, these mussels have few predators and, when left unchecked, can grow to extreme numbers. They have now been sighted as far south as Baton Rouge and as far east as the Hudson River.

> A BMDO PULSED POWER DEVICE OFFERS A PROMISING, NONPOLLUTING WAY TO DISCOURAGE ZEBRA MUSSELS FROM LIVING IN THE COOLING SYSTEMS OF POWER PLANTS.

Zebra mussels are inclined to live in and clog the cooling systems of power plants and ships costing utilities and shipbuilders millions of dollars to remove them. Many power plants have had to use expensive control systems that release toxic chemicals such as chlorine into the water. Most ships have no control strategies at all and may be forced to completely replace their cooling systems every few years.

Working with a pseudospark switch developed at the University of Southern California for BMDO's kinetic energy weapons, ODU has found a promising, nonpolluting way to discourage zebra mussels from residing in the cooling systems of power plants. The technology acts essentially as an electric fence, continuously applying ultrashort pulses of electricity. The pulses stun the mussels, preventing them from clinging to the surface of the cooling systems.

The pseudospark switch can also eliminate zebra mussels from the ballast water on ships. ODU is part of a consortium to develop this application through a $2 million project for the Advanced Research Project Agency's Technology Reinvestment Project. Demonstrations to eliminate or stun brine shrimp have been successful—good news, since they are considered to be hardier and therefore harder to treat than zebra mussels. The consortium, called CASRAM, includes ODU, the South Tidewater Association of Ship Repairers, the Commonwealth of Virginia, and the City of Norfolk.



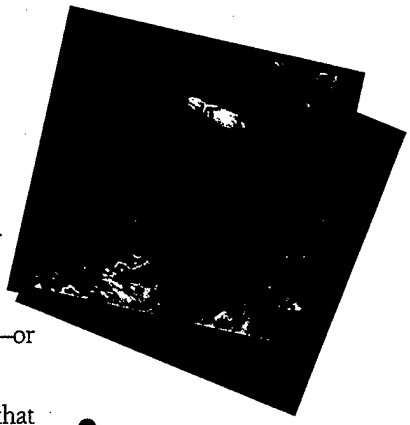
ODU's pseudospark switch, pictured above, acts as an electric fence, continuously applying ultra-short pulses of electricity to the plants' cooling systems.

ODU researchers have also developed a more accurate pulse power switch for BMDO that uses lower current and lower voltages, which can, in addition to defense, be used to treat cancer and other diseases. Still in the research stage, the switch is producing pulses that attack abnormal cells without affecting normal ones. In fact, researchers collaborated with the Eastern Virginia Medical School in a study that confirmed the ability of shorter, submicrosecond pulses to change the inside of the cell while leaving the membrane intact, which could be useful in reducing or eliminating cancerous tumors.

About The Technology

The semiconductor-based pulse power switches can produce ultrashort electrical pulses of 1 million watts or more. They are made of silicon-doped gallium arsenide, which is counter-doped with copper atoms to produce a semi-insulating material of GaAs:Si:Cu. The switch is activated with a Nd:YAG laser, which energizes electrons that the copper impurities trap. The electrons remain in this energy state for several microseconds, and current flows through the switch as long as they are trapped. A second laser is used to turn off the current. Optical control of the switch allows researchers to vary the pulse duration with extremely high accuracy. The pulse duration can be as short as 100 picoseconds, making it the fastest gatable high-power switch known. These switching speeds can deliver short bursts of intense electrical power to remove zebra mussels without creating significant levels of heat.

Software To Help Detect Forest Fires



In 1994, forest fires burned over 3.8 million acres of woodlands. LNK's technology may help reduce this number.

In charge of thousands of acres of densely wooded and rugged terrain, forest rangers face many challenges in detecting, tracking, and extinguishing fires. While sensor-based systems have been used at ranger stations, they tend to be expensive, inaccurate, and inadequate. For example, such systems often send false alarms and are unable to provide information about the extent of a fire—or its potential to spread and damage surrounding areas.

As a result, rangers are still limited in their ability to fight the large number of forest fires that occur each year in the United States. In 1994, these fires burned more than 3.8 million acres of woodlands, took 27 lives, and cost the taxpayers about $1 billion.[3]

Using technology that BMDO initially funded, LNK Corporation (Riverdale, MD) is codeveloping the first commercial sensor system to help rangers quickly detect and fight forest fires. LNK is integrating its artificial intelligence software into a remote sensor camera developed by AI Atlanta (Atlanta, GA). Merging artificial intelligence and sensors is a big plus for forest rangers because they will be able to accurately locate forest fires and avoid false alarms caused by mistaking, for example, fog for smoke. Rangers will also be able to access information about wind flow patterns, which influence where and how quickly fire spreads.

LNK'S INTELLIGENT SOFTWARE SYSTEM WILL HELP RANGERS REMOTELY DETECT AND MAKE DECISIONS ABOUT CONTROLLING FOREST FIRES.

In addition, the team is incorporating geographic information system (GIS) capabilities into the system, allowing rangers to locate gas lines, geological structures, and the closest firefighting teams in the area. Rangers will also be able to identify nearby residential populations. With such information, they will be able to quickly call upon the closest and best resources for putting out fires. They will also be able to evacuate any threatened areas. The team's prototype is being built through an SBIR contract with the U.S. Department of Agriculture.

In addition to fire fighting, LNK's software has a variety of other applications that involve scanning and interpreting information. Initially developed to detect motion patterns in imagery through a BMDO SBIR contract, the software could be used for surveillance systems, machine vision, and interactive simulation.

LNK is marketing its artificial intelligence software as Image_Lib, an image processing and analysis toolbox. In a teaming arrangement, LNK has adapted the toolbox to Adaptive Solutions, Inc.'s (Beaverton, OR), parallel coprocessor, called CNAPS®. CNAPS® is one of the cheapest parallel coprocessors on the market.

About The Technology

For BMDO, LNK needed to develop a system that could quickly recognize patterns, track those patterns from frame to frame, and interpret them in the context of military environments. To meet these needs, LNK developed hybrid software that integrates components of two artificial intelligence systems. First, it incorporates neural networks, which are algorithms or devices that resemble the biological circuits of the brain. It also uses expert systems, which make decisions based on a database of knowledge. This image processing combination fuses data from multiple sensors to track and recognize objects of interest.

The LNK software algorithms can automatically classify terrain or pick out objects. The software can identify many moving targets against a cluttered, moving background, as well as the shapes, positions, and velocities of those targets.

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[3]The Fires of '94...N. Sampson; *The Virginia Forester,* Winter 1995, p. 8.

New Gas Generators Reduce Accident Risks

One of the biggest public safety problems that producers of compound semiconductor materials face is the danger posed by toxic gases required for production. These concerns are particularly important for compound semiconductors, which require substantial portions of arsenic, antimony, or phosphores. Such gases can be extremely poisonous—so toxic that a ruptured canister can present risks to workers and the environment. And chances of such ruptures are not remote; even facilities with *good* records often have a costly and potentially environmentally hazardous release of the toxic gas every few years.

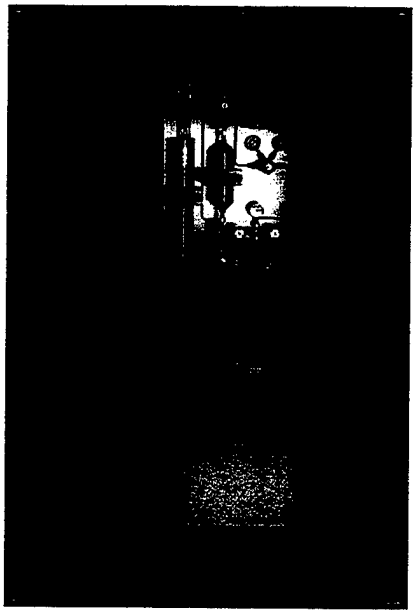
But these potentially harmful substances are essential for making compound semiconductors for sensors and fiber optics. With the help of a BMDO SBIR contract, Electron Transfer Technologies, Inc. (Princeton, NJ), has solved this problem. It has developed a solid sublimation method to generate gases, such as arsine, stibine, and phosphine, on site at the semiconductor manufacturing facility.

THROUGH A BMDO-FUNDED SBIR CONTRACT, ELECTRON TRANSFER TECHNOLOGIES, INC., HAS FOUND A SAFER WAY TO GENERATE TOXIC GASES NEEDED TO MAKE SEMICONDUCTORS.

Facilities using these generators can produce gas on demand, using raw materials that can be transported and stored as solid blocks, rather than volatile stored gas. Equally important, the quality of the gas from these generators is also higher than that of traditional bottled sources, lowering the cost of chips produced and increasing production rates. Electron Transfer has fully developed, and is now selling, arsine and stibine generators; the company is also developing phosphine, hydrogen selenide, and chlorine generators.

One of the first users of stibine generators is Sensors Unlimited, Inc. (Princeton, NJ), which has received great interest from the environmental community—not in the generators themselves, but in the sensors that were made using these generators. In a dual-use Air Force SBIR contract, Sensors Unlimited has been using Electron Transfer's technology to develop a laser in the 3.3 micron range of the infrared electromagnetic spectrum.

While the laser's military role will be to detect chemical warfare agents on the battlefield, it can also detect methane—a greenhouse gas that is very difficult to control because it is so difficult to detect. Several sensor companies are now interested in purchasing this sensor for environmental monitoring. With Electron Transfer's gas generator, Sensors Unlimited will be able to make its detectors more safely—a double environmental bonus as we approach the 21st century.

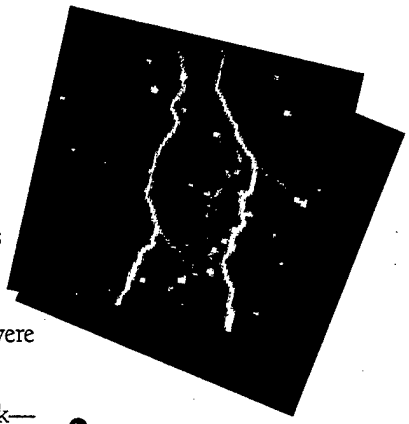


Electron Transfer Technologies, Inc., has developed a solid sublimation method to generate gases, such as arsine, stibine, and phosphine, on site at the semiconductor manufacturing facility. Pictured above is the arsine generator.

About The Technology

The point-of-use generators can be used to produce compound semiconductors such as gallium arsenide, indium phosphide, indium antimonide, and cadmium selenide/zinc selenide. The primary applications for these semiconductors are in optoelectronics (fiber optics and sensors) and high-frequency communications. In addition, arsine and phosphine are widely used to produce dopants for silicon-based semiconductors, and chlorine is used in etching semiconductors. Electron Transfer has eight patents for its technology related to point-of-use chemical generation.

Neural Networks See Sunny Commercialization Prospects



A better understanding and knowledge of severe weather is the first step toward lessening its often costly and sometimes deadly impact.

Severe weather—such as blizzards and flooding—costs the United States hundreds of lives and billions of dollars every year. Although many of these losses could be avoided with sufficient precautions, the hit-or-miss history of weather prediction has resulted in a public often reluctant to believe forecasters' warnings. A better understanding and knowledge of severe weather is the first step toward lessening its often costly and sometimes deadly impact.

Using satellite images as input, KTAADN, Inc. (Newton, MA), has developed a neural network—an electronic network modeled after the human brain—that can predict cloud cover for up to 4 hours into the future. This information can be an important tool for both weather forecasting and airborne optical observation.

> Among other applications, KTAADN's technology may help air traffic controllers direct and land planes more safely.

The commercial applications for cloud-cover prediction range from simply improving the planning of outdoor events to tracking and predicting potentially life-threatening electrical storms and other cloud-related weather. KTAADN's technology may improve the ability of air traffic controllers to safely direct and land planes. It could also allow builders to plan critical construction steps, such as pouring concrete, without losing thousands of dollars to unexpected rain. Better knowledge of when and where to expect rain may allow farmers to schedule planting and crop spraying for the best results. Observatories and other weather-dependent interests such as outdoor entertainment may also benefit from the improved knowledge of when and where clouds will be.

BMDO originally funded this work for treaty verification and missile defense. The R&D was to enhance the detection of optical signatures ranging from ultraviolet to infrared, overcoming the obstacle of clouds, which often obscure important measurement targets. The prediction capability of KTAADN's neural network allows planners to choose the best parameters (such as time of launch, geographic location of optical sensors, and altitude of airborne optical sensors) to collect the most complete and accurate data possible.

About The Technology

KTAADN has constructed a neural network designed to predict cloud cover by using satellite images. Using a neural network for information processing, KTAADN can study the satellite images of cloud formations and predict cloud-free fields of view on a localized scale up to 4 hours into the future. Regional forecasts can be extended to longer time periods.

Modeled after the human brain, neural networks simulate complex networks of neurons with computer circuitry and software. Initial input conditions are chosen to describe a complex system, and the network uses these inputs to generate a new set of variables. This new set is used as input for a second iteration. The processing is repeated until an optimal state is reached, and the system is said to have "learned" the solution. Neural networks can be combined with knowledge data bases describing a system's history to produce a predictive processor.

Crime causes considerable harm to innocent people, with more than 4.4 million Americans as victims of aggravated assault, robbery, rape, or murder in 1993.[1] It also harms the Nation financially. According to the most recent National Crime Victimization Survey in 1992, the 33,649,340 assaults, burglaries, motor vehicle thefts, personal and household thefts, rapes, and robberies cost victims about $17.6 billion in property and monetary losses, medical expenses, and lost time at work.[2]

Law enforcement officials are presented with serious challenges in catching criminals and preventing crimes from ever happening. They could benefit from improved technologies such as portable and broader bandwidth communications equipment and nonintrusive drug detection systems.

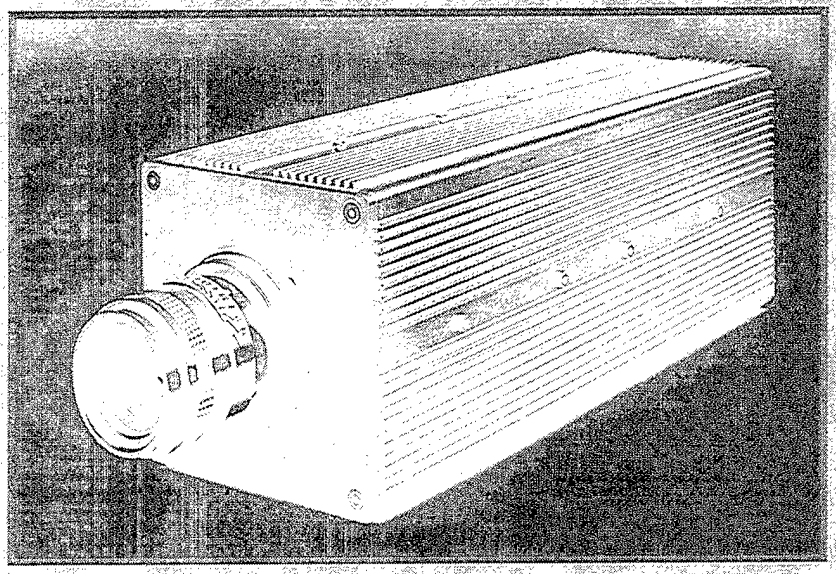
Today's market. The financial market for law enforcement technology is not yet defined; technology users include State, local, and Federal law enforcement agencies, commercial groups interested in industrial security, and related organizations. Most of these organizations have extremely tight budgets, which translates to the need for low-cost technology.

Tomorrow's opportunity. BMDO technology developed to protect the United States from ballistic missile attacks may likewise be used to protect families, homes, and businesses from crime. BMDO has funded leading-edge technology in communications, information systems, sensors, materials, and optics that may help the law enforcement community do its job better and more safely. As always, the challenge is to take the technology and develop it into high-quality, low-cost, easy-to-use products. Five such technologies are described in the following section.

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[1] *Handguns Used in More Than One Million Violent Crimes, The Use of Semi-Automatic Guns in Murders Is Increasing* (public information release), U.S. Department of Justice, July 9, 1995, p. 1.

[2] *The Costs of Crime to Victims: Crime Data Brief,* U.S. Department of Justice, Bureau of Justice Statistics, February 1994, p. 1.



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LAW

ENFORCEMENT

Uncooled Infrared Sensor Gets Warm Reception

Businesses are concerned about theft in the workplace, especially in large warehouses and industrial facilities. According to U.S. Department of Commerce statistics, roughly 30 percent of the U.S. companies that fail do so because of employee theft.[3] And with an average $23,500 profit for the culprit, this criminal activity is nearly 100 times more profitable than the average armed robbery. The threat of theft has prompted interest in using infrared (IR) detectors for protection from break-ins after business hours. Since these sensors detect heat rather than visible light, they can "see" and record the activities of burglars in near total darkness.

Most IR sensors require cryocoolers, which add to their cost and limit operation time. But using a design concept funded by a BMDO SBIR contract, Sensors Unlimited, Inc. (Princeton, NJ), has developed and is selling a portable near-IR camera called the SU128-1.7RT that does not require cooling. The camera costs about $25,000, about four times cheaper than IR imagers used in the Persian Gulf War.

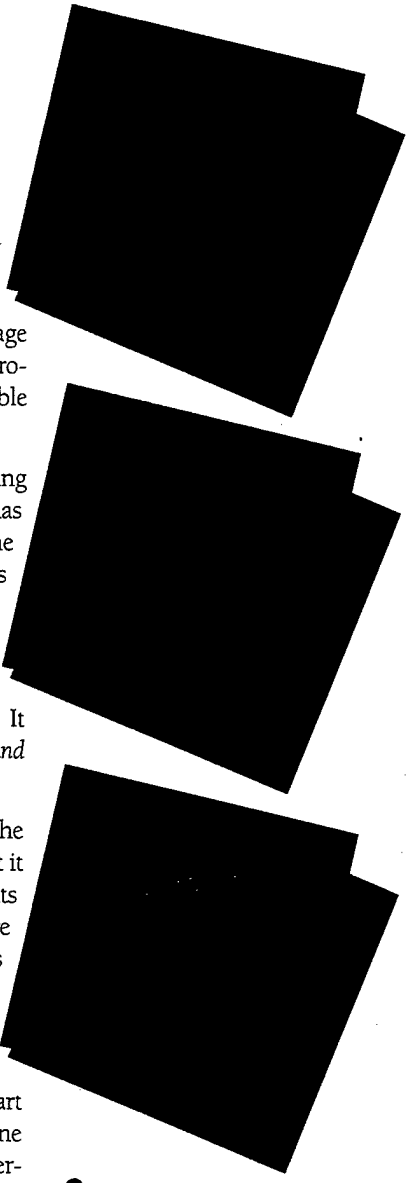
Costing about $25,000, Sensors Unlimited's award-winning uncooled infrared cameras are about four times cheaper than infrared imagers used in the Persian Gulf War.

Sensors Unlimited recently won a 1995 Commercial Technology Achievement Award for its new product from *Laser Focus World*. It also won new product awards from *Photonics Spectra* and *Lasers and Optronics* magazines.

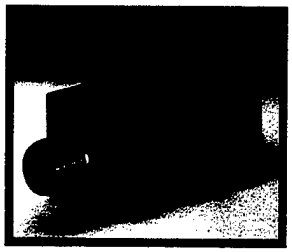
Pursuing the law enforcement market, the company has sold the camera to security organizations for surveillance applications. But it has other applications as well. For example, manufacturing plants have bought it to detect "hot spots" that may lead to parts failure in manufacturing processes. It can also be used for other manufacturing applications, such as sorting out fungus-contaminated food on the production line.

In addition, the company has sold a camera to an environmental organization for recycling applications. By reading short-wavelength light projected onto a pile of plastic or glass bottles, the IR sensor can help recyclers sort various types of plastic and glass containers. And in the art department, Sensors Unlimited is working closely with museums, using the sensors to determine whether a charcoal sketch or another painting exists underneath a work of art. The sensor can determine not only the authenticity of the painting, but also what the artist may have originally planned to paint.

With further development, the camera will allow medical researchers to observe microscopic organisms without having to tag them by fluorescence. Tagging cells with dyes is generally required when using current technology, which can detect cells only at the shorter wavelengths. The uncooled IR sensors are sensitive enough to detect many types of cells and other matter that naturally fluoresce at the longer wavelengths.



Some of the camera's applications include law enforcement, semiconductor production, and medical imaging.



This compact, uncooled infrared camera costs less than its cryogenic competitors.

About The Technology

Eliminating cooling needs has reduced the size and weight of near-IR cameras, making them much cheaper than their cryogenic counterparts. Sensor Unlimited's portable camera is 4 x 4 x 12 inches. Its only requirement is power from an electrical outlet or 12 volts of direct current. The focal plane array of the SU128-1.7RT room-temperature near-infrared camera consists of an indium gallium arsenide photodiode array (128 x 128) integrated with a silicon readout multiplexer using indium bump bonding technology. (NASA and the Jet Propulsion Laboratory funded SBIR contracts for the focal plane array technology used in the camera.) The camera can provide onboard analog-to-digital conversion and digital output. Up to 512 frames can be stored in memory on the internal control board for subsequent display or storage.

[3] Employers Don't Have to Live with Stealing...L. Croghan; The *Ottawa Citizen*, June 3, 1995, p. e3.

Image Enhancement Expertise Comes To The Courtroom



This frame of a time-lapse video, taken from an automated teller machine, pictures a car behind the man—a possible link to the crime.

The technology Al Tietjen uses to help catch crooks is not really all that new. After all, digital image enhancement has been around since the 1970s. In fact, many desktop publishing software programs provide simple digital enhancement features, and many other complementary programs provide a more sophisticated suite of enhancement algorithms.

However, the use of this technology in law enforcement is new, partially because today's image-producing programs cannot provide the detailed documentation needed in a criminal investigation. Therefore, police departments must retain the services of specialists who can defend their image enhancement routines in court. Tietjen, a contractor with Nichols Research Corporation at the BMDO imaging facility known as Innovative Science and Technology Experimentation Facility (ISTEF) (Kennedy Space Center, FL), is one such specialist. He enhanced images in what became the first trial in the United States to admit digitally enhanced video images as evidence.

In this case—the 1989 abduction and murder of Lori Auker, of Point Township, Pennsylvania—investigators obtained time-lapse video from the camera of an automated teller machine near where Lori was last seen. The police found three fuzzy pictures from the video they thought might help them. In the background, they could make out a car entering and leaving the camera's field of view. The second picture showed a woman standing outside the passenger side of the car, wearing clothes that matched Lori's outfit that day.

BMDO-funded technology enhanced digital video images for a case that became the first U.S. trial to admit such images as evidence.

Though the police had gathered a lot of supporting evidence, they still needed to link the car in that picture to the suspect, Lori's former husband. Their only hope was digital image enhancement. After some preliminary work with several groups, they turned to BMDO/ISTEF, which agreed to donate its technology and facilities, and to Al Tietjen, who donated his time to the project. During the trial an expert witness from General Motors used Tietjen's enhanced images to identify the make and model of the car to within 2 years. That information, combined with other testimony, established a detailed chronology of the suspect's whereabouts and activities, and helped secure a conviction.



The image of the car was enhanced and identified in court as the same type of car that Robert Auker drove the day of the abduction.

Since then, Tietjen has assisted in many other investigations, including the celebrated case of the Gainesville Slasher, which involved the murder of five students at the University of Florida. These efforts began demanding more resources than BMDO/ISTEF could realistically provide, so Tietjen has continued this work as a part-time consultant with Spaceport Technologies, Inc. (Titusville, FL).

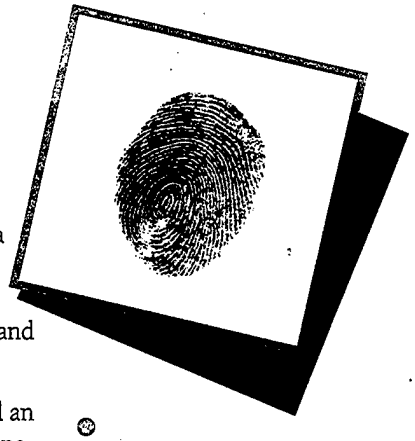
Tietjen's experience in the field has made him realize that police departments need better technology to do their jobs. There are simply more cases than qualified specialists, or the funds to hire them. Therefore, Tietjen is developing expert system software to analyze the imagery automatically, select algorithms, adjust control parameters, and provide the detailed documentation needed to defend digital image enhancement in court.

About The Technology

Digital image enhancement uses computer hardware and software to digitize a picture, enhance certain features, and send the output to video, hard copy, or computer file. The enhancement algorithms consist of a specialized suite of filters and transforms. Tietjen's expert system software will allow a nonspecialist to use these algorithms without detailed knowledge of how they work. Because the software is targeted at law enforcement needs, he is tailoring it to the unique problems of enhancing time-lapse videotape recordings and photography.

Much of Tietjen's expertise in this field was developed while working at BMDO/ISTEF and earlier aerospace positions. ISTEF is dedicated to evaluating sensor technology used in ballistic missile defense systems.

BMDO-Funded R&D May Help Officials Catch Drug Traffickers



One of MLANS' many potential applications is for fingerprint identification.

From detecting illicit drug factories in the clutter of trees to searching through mug shot data banks at the police station, object identification systems have many uses in law enforcement. These systems are now using powerful sensors that can collect large amounts of data, so they will need intelligent algorithms—technology that can sort through the flood of sensory data and pinpoint specific objects.

With BMDO funding, Nichols Research Corporation, or NRC (Wakefield, MA), has developed an intelligent algorithm called Maximum Likelihood Adaptive Neural System (MLANS). The company is now modifying this work to identify objects of interest for the law enforcement community.

One version of the algorithm is a system that, when used with sensors, will help detect planes carrying drug contraband over the Caribbean; NRC is working with the Air Force Materiel Command's Rome Laboratory and the Advanced Research Projects Agency on this sponsored project. NRC has also pursued applications such as fingerprint identification, enabling a person to enter a secure area by using his or her thumb rather than a code or card key, or by using a combination of both. Another potential application for MLANS is detecting electronic criminal activities on the national information highway and other data sources.

USING BMDO-FUNDED TECHNOLOGY, NICHOLS RESEARCH CORPORATION IS DEVELOPING A SYSTEM THAT CAN DETECT SMALL PLANES CARRYING ILLICIT DRUGS OVER THE CARIBBEAN.

MLANS is better than other alternatives because it can quickly adapt to changing conditions, and it is also affordable. Dr. William Schoendorf, a vice president at NRC, explained, "We've applied MLANS to a very large number of very different problems and it has always been successful." For example, jointly with an ophthalmology company, NRC is developing an automated tool for diagnosing eye diseases. NRC has also developed a MLANS-based system for oil exploration. By correlating electrical, acoustical, and other geophysical data taken while drilling with the limited rock samples from the bore holes, MLANS can identify signs of oil and predict such difficult-to-measure properties as rock permeability. NRC currently markets services of this well-log analysis system jointly with a well-log analysis company.

Looking at smart highway applications, researchers at NRC have demonstrated MLANS as part of a collision avoidance system during a U.S. Army test of unmanned vehicles. The system took a stream of images from a dashboard-mounted camera and identified and tracked both defined and undefined objects. For NASA, NRC has developed a system for search and rescue missions that can detect downed aircraft in heavily wooded areas. The BMDO SBIR program originally funded NRC's work for space-based applications.

About The Technology

NRC designed MLANS to analyze sensor data streams and adaptively classify and track objects of interest while suppressing background clutter and noise. The system combines the worlds of expert systems and neural networks, the system is affordable, adaptive, and fast learning.

MLANS can use complicated models developed by human experts or construct statistical models of what objects look like. It then refines the models as more data are received. The program analyzes the signal or image, classifying the information in each unit according to its attributes. Values for each attribute are used in a multidimensional model that combines statistical properties with shape and motion to provide a "fuzzy classification" of the class of objects to which the pixel or element belongs. The algorithm achieves the Cramer-Rao bound (a measure of statistical likelihood), indicating the fastest possible learning and accuracy. MLANS has been encoded in a variety of programming languages and runs on several types of systems, including personal computers.

BMDO-Funded Electronics To Aid Law Enforcement

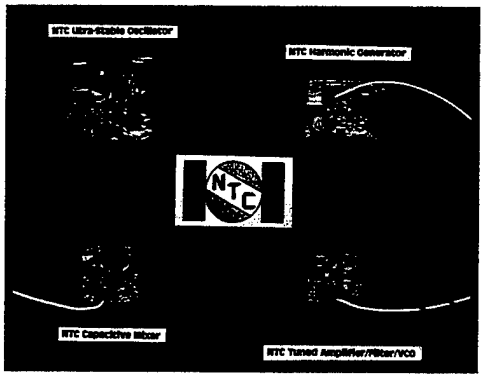
Wireless communications devices, such as mobile phones, are important for police work, allowing law enforcers to coordinate missions in the field and monitor a suspect's conversation. In the continuing push to produce smaller and more affordable wireless transmitters and receivers, a single electronic circuit chip remains a challenging goal.

The radio frequency (RF) circuits of wireless systems use inductor elements for tuning and matching. The inductors increase the size of the RF circuit because larger electronic packaging is needed. Therefore, the larger RF circuit has limited applications in areas where miniaturization is important.

Under BMDO SBIR funding, Neillen Technologies Corporation, or NTC (Lanham, MD), has created a new inductorless technology for RF circuits that could solve this problem. The company's technology will allow electronic communications devices to be produced that are smaller and consume less power than conventional technology. Law enforcement could use this technology in remote sensing, alarms, surveillance, and intelligence gathering.

> NTC's technology will make smaller and lower power electronic communications devices possible for the law enforcement community.

To help bring inductorless technology to market, Neillen has signed an exclusive licensing and royalty agreement with National Semiconductor, a world-renowned semiconductor manufacturer. Under this agreement, NTC will design inductorless circuits for specific applications and National Semiconductor will manufacture them in silicon. In addition, National Semiconductor will match BMDO's SBIR funding of NTC to develop six printed circuit board (PCB) and integrated circuit prototypes.



NTC's inductorless devices eliminate the need for complex and bulky electronic packaging. Pictured above is NTC's first collection of prototype surface-mounted printed circuit boards for its inductorless circuits.

In addition to police work, NTC's inductorless technology can be used in the telecommunications, transportation, biomedical, and entertainment industries. For example, these devices can improve commercial RF electronic communications equipment, such as AM/FM navigation dispatch radios and cellular mobile phones. They also can be used for security alarms, remote-control toys, and instrumentation and test equipment.

About The Technology

NTC's inductorless technology produces an inductor-like function in semiconductor circuits. This capability eliminates the need for complex and bulky electronic packaging, so RF circuits can be smaller. All tuning and matching circuitry is assembled directly on a single silicon chip. Since this is the first technology to allow fully functional, monolithic RF integrated circuits in silicon, it will produce RF electronic devices that significantly outperform and are more cost-effective than conventional RF circuits.

With the help of BMDO SBIR funding, NTC is developing PCB, hybrid, and integrated circuit versions of its core RF circuits. These circuits include ultrastable oscillators, voltage-controlled oscillators, harmonic generators, tuned amplifiers, tuned bandpass filters, and capacitive mixers. It is also designing the RF electronics for a new class of integrated transmitter and receiver subsystems and active antennas. Because these RF electronics have complementary interfaces, when used as a system they perform better than existing commercial products using components from multiple vendors.

Compact X-Ray Detects Hidden Explosives



Golden Engineering's portable x-ray detector is ideal for field personnel, who can easily tote these detectors to any site.

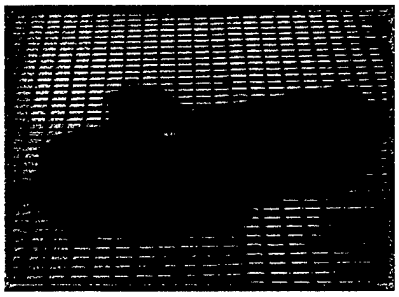
According to the U.S. Department of Justice, roughly 28,000 actual and attempted bombing incidents occurred in the United States between 1973 and 1992, causing more than $231 million in property damage, 3,590 injuries, and 502 deaths.[4] In many of these cases, criminals hid their explosives in inconspicuous containers and packages, such as suitcases, briefcases, and trash cans.

As a result, law enforcement agencies have become interested in portable x-ray detectors, which noninvasively detect explosives inside suspicious packages. While x-ray equipment has existed for years, it has weighed hundreds of pounds and has been too heavy to lug in and out of buildings. It has also been too large to place in tight spaces. Portability allows agents to address situations where a few minutes saved could prevent serious damage to life and property.

THE COMPACT X-RAY DEVICE, FUNDED BY BMDO, CAN HELP BOMB SQUADS AND POLICE OFFICERS DETECT CONCEALED CONTRABAND SUCH AS EXPLOSIVES AND DRUGS.

Using BMDO-funded R&D, Golden Engineering, Inc. (Centerville, IN), has developed and is marketing a portable, 30-pound x-ray system that solves this problem. When alerted by a bomb threat, law enforcement officers can take x-rays in minutes instead of tens of minutes needed with other technology, giving squads extra time to evacuate people from the area and dispose of the bomb, if necessary. The device's portability, penetrative power, and ease of use also lends itself to other law enforcement applications. For example, it can be used to detect bullet fragments in objects such as furniture and can reveal weapons, drugs, and other contraband in closed containers.

In addition, manufacturers and utilities may use the x-ray detector to cost-effectively address quality control problems, since the system's portability allows them to inspect items in hard-to-reach areas. For example, the detector can verify the correct position of a system's internal components, examine utility lines and cables for internal damage, and check gas and oil pipelines for corrosion.



Despite its small size, the pulsed device has 150,000-volt peak output that will penetrate one-half inch of steel.

Golden Engineering first developed this detector for the BMDO Satellite Attack Warning and Flight Assessment (SAWAFE) project in conjunction with Los Alamos National Laboratory. In the SAWAFE project, the device is designed to test fiber-optic sensors that can detect radiation from a space-based nuclear explosion.

About The Technology

Golden's entire x-ray system—including pulsed power source, battery pack, remote cable, intensifier screens, instant-type x-ray film, and film developing unit—fits into one carrying case and weighs just 30 pounds. Instead of using a bulky industrial-type power source weighing more than 40 pounds, the new x-ray system incorporates a pulsed power source that is about 3 inches in diameter by 10 inches long and weighs less than 5 pounds. Despite its small size, the pulsed device has 150,000-volt peak output that will penetrate one-half inch of steel. The power supply for the pulsed device is a 7.2-volt removable, rechargeable nickel-cadmium battery pack that fully recharges in 1 hour. The battery can provide up to 2,500 x-ray pulses per charge, each lasting 60 nanoseconds. About 50 pulses will penetrate quarter-inch steel piping, revealing detail about what is inside the pipe. To use the device, operators attach the battery, set the desired number of pulses, and fire the unit using either the remote cable or time delay button.

[4] *Sourcebook of Annual Justice Statistics*, U.S. Department of Justice, Bureau of Justice, 1993, p. 411.

Industrial process technologies—technologies that affect how companies produce goods and services—are critical to America's productivity. According to Jack Swindle, chairman of the National Center for Manufacturing Sciences (NCMS) Board of Directors, "All too often, American manufacturers fail to realize it's not what they produce, but how they produce it that determines customer satisfaction, sustained profitability, and long-term global competitiveness."[1]

Advanced technology allows U.S. manufacturers to improve their processes and techniques, and, in some cases, reduce the environmental impact of manufacturing. Revolutionizing U.S. manufacturing operations, these technologies can drive costs and cycle times down, while gearing productivity and quality up—important factors for companies that want to improve profitability and customer satisfaction.

And, as more companies integrate these technologies into their operations, the U.S. manufacturing industry gains a competitive advantage in the global marketplace. What types of technology are we referring to? Manufacturers can benefit greatly from innovations in everything from harder materials for stamping and punching to artificial intelligence software that can detect machine defects and react to unforeseen events.

Today's market. Manufacturing is the backbone of American industry, supporting about 47 percent of the Nation's total employment (17.8 million jobs in direct manufacturing and 34.1 million in secondary jobs) in 1993.[2] Real output for U.S. manufacturing, overall, is projected to grow at an average annual rate of 2.4 percent between 1992 and 2005. U.S. manufacturing's direct share of the economy accounts for over one-fifth of the gross domestic product, and nearly half of the total U.S. economic activity depends at least indirectly on manufacturing.[3]

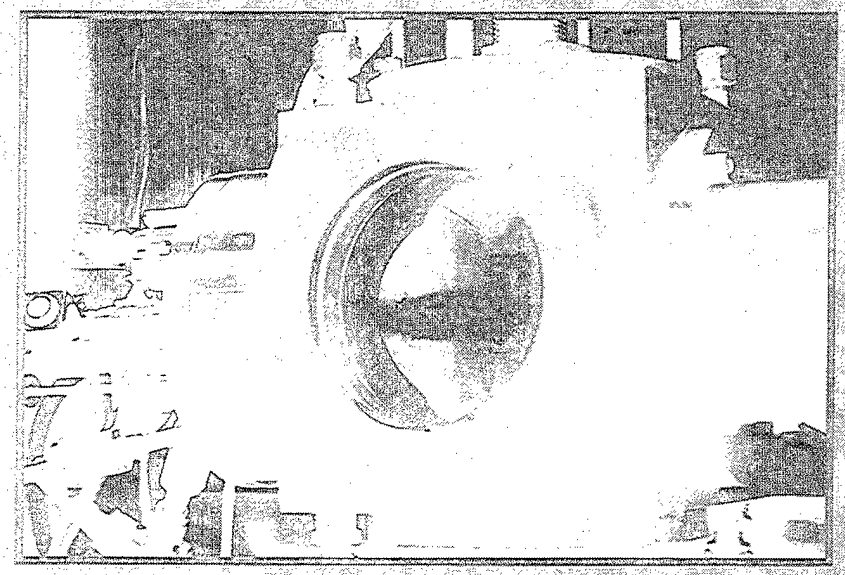
Tomorrow's opportunity. To meet various needs for ballistic missile defense, BMDO has funded the development of advanced technology in neural networks, lasers, optics, and materials. While improving the Nation's defense, much of this technology also offers strategic benefits to the American manufacturing community, helping companies to significantly improve industrial capabilities. The following section describes eight of these innovations.

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[1] Process Technologies Offer Strategic Benefits to American Manufacturing Community and the Nation...*Focus*, May 1995, p. 1.

[2] American Manufacturing Crucial to Job Development, Economic Prosperity of the Nation...*Focus*, March 1994, p. 1.

[3] U.S. Manufacturing: The Big Picture...*Focus*, January 1995, p. 8.



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MANUFACTURING

Adaptive Optics May Save Millions For Manufacturers

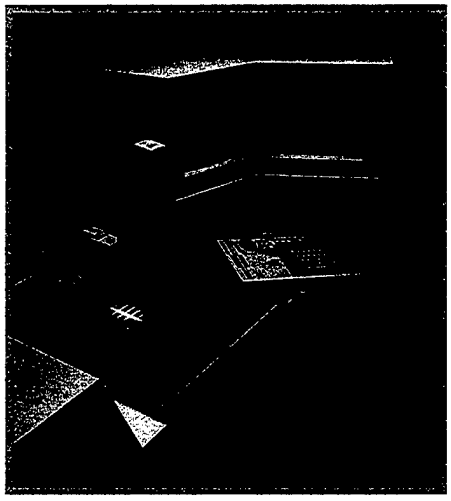
In the early 1990s, the Department of Defense declassified a set of technologies called adaptive optics, which had been developed with considerable funding from BMDO. Adaptive optics were immediately recognized for their potential to help the astronomical community because they allow Earth-based telescopes to measure and correct optical distortions that atmospheric turbulence can cause.

But few people noticed the technology's potential for more terrestrial applications on the manufacturing floor—except a small firm called AOI International (Lowell, MA). Using adaptive optics technology developed for BMDO reconnaissance and scientific imaging systems, AOI is making automated optical inspection systems that can save manufacturers millions of dollars. This effort is being funded by the Advanced Research Projects Agency's Technology Reinvestment Project.

AOI IS DEVELOPING SYSTEMS THAT CAN SPOT FLAWS AS THEY OCCUR IN PRINTED CIRCUIT BOARDS, REDUCING THE COST AND WASTE FROM SCRAPPING FINISHED PRODUCTS.

AOI's systems are particularly attractive to the printed circuit board (PCB) industry, which annually throws away millions of dollars worth of finished boards because manufacturers cannot spot flawed PCBs before product completion. To improve manufacturing yields, PCB makers need inspection systems that can spot flaws as they occur.

Because AOI's adaptive optics can enhance the efficiency of PCB plants, the company believes its technology will give domestic manufacturers a competitive edge in world markets. And, while AOI is focusing its research on the sizable PCB manufacturing industry (which accounts for over half of the billion-dollar market for automated optical inspection systems), future markets also exist in the manufacture of food and wood products, cars, plastics, and pharmaceuticals.



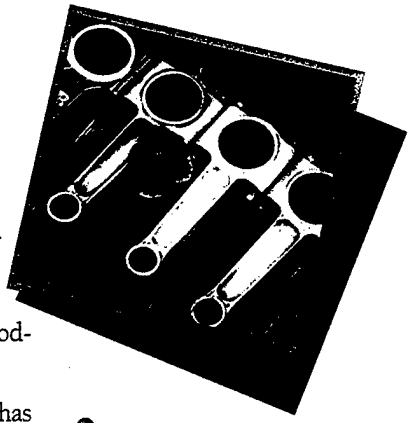
Pictured above is a defect evaluation and repair station.

About The Technology

AOI International's innovations are based on a technology called shearing interferometry, a method for sensing the phase difference in wavefronts. With this information, adaptive optic systems can change the focal point of so-called rubber mirrors (mirrors made of a piezoelectric ceramic that change their shape in response to an applied voltage) to eliminate these phase differences and produce flawless images. BMDO funded this research to accurately track and destroy incoming missiles with high-energy laser beams.

In the adaptive optics systems developed for military and astronomical uses, shearing interferometry is used to measure the phase difference between a laser "guide star" (whose wavefront characteristics were known) and the object being imaged. AOI's interferometers measure the phase differences caused by changing process conditions during highly detailed and finely dimensioned manufacturing operations, so that the imaging system can adjust accordingly. As a result, AOI's inspection systems can continuously change focus, providing the dynamic image quality control needed to spot flaws during the manufacturing process.

Composites Meet Mass Production Requirements



MMCC has already produced automotive parts, such as the connecting rods pictured above.

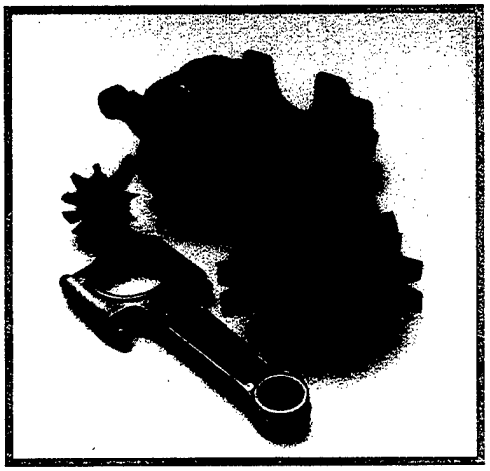
No matter how good a product or material is, it will not be widely used commercially if it cannot be economically mass-produced. Such is the case with some of the strong, durable, lightweight cast composites developed for military use. While ideal for high-value parts in automobiles, aircraft, and even sporting goods, these materials are not widely used in consumer products because they cost too much to mass produce.

> MMCC has produced connecting rods for Ferrari automobiles and is also developing brake calipers with AlliedSignal and Ford Motor Company.

Metal Matrix Cast Composites, Inc., or MMCC (Waltham, MA), has developed a faster and more affordable way to manufacture high-strength, lightweight materials called metal matrix cast composites. The company's method could make production of these materials 25 times faster than current methods. Such speed dramatically lowers production costs and allows composite materials—which are stronger and lighter than steel—to be widely used.

BMDO originally funded this work at the Massachusetts Institute of Technology, or MIT (Cambridge, MA), to produce less expensive metal matrix cast composites for missile parts. A researcher at MIT later licensed the technology and formed MMCC to commercialize the process. MMCC has since received a BMDO SBIR contract to continue this work.

So far, MMCC has used its expertise to produce connecting rods for Ferrari automobiles and is developing brake calipers with AlliedSignal and Ford Motor Company. MMCC has also used the technology to manufacture electronic packaging components and heat sinks for commercial and military applications.



Pictured above are a brake caliper, rotors, and a connecting rod. The brake caliper and connecting rods have been manufactured using MMCC's process. MMCC plans to eventually make rotors.

Metal matrix components offer advantages over their heavier steel counterparts because they retain their strength under high temperatures and yet can be cast into complex shapes for specialized uses. MMCC's casting process is expected to increase stiffness and improve thermophysical properties over conventionally cast reinforced structural components with little increase in cost. The process will also strengthen unreinforced cast components through its complete material flow into mold spaces and its accurate control of the mold cooling process.

MMCC uses low-cost molds, which lend themselves to rapid prototyping of cast components. Wet and dry friction performance or built-in lubricity materials can be molded using MMCC's process, and resulting components require little followup finishing, even for high-tolerance parts.

About The Technology

MMCC's method does not require a vacuum pressure vessel surrounding the mold or furnace; it uses a pressure vessel only for pressurization and infiltration of the melt, while cooling is controlled to enhance directional solidification. The process usually takes only about 10 minutes depending on the amount of material used and its composition. Therefore, items can be cast faster, and composites are more completely bound by the matrix. Tightly controlled cooling results in accurately shaped complex parts with desired grain orientation, boundary conditions, and surface control.

MMCC has an exclusive worldwide, all-fields-of-application license for the pressure infiltration process and related tooling materials, and it has filed patents in North America, Europe, and Asia.

Intelligent Software Reacts To Unforeseen Events

Although computer automation has revolutionized the factory floor, the complex control systems that have evolved to handle this automation are anything but flexible. Most control systems have been designed to handle predetermined situations, and are paralyzed when confronted by an unplanned event. A mainframe-controlled system seeks direction from its central source on how to handle anything that seems abnormal; after a period of time the central source provides a solution to the control system's dilemma. This top-down approach can drastically slow down processes—leading to lost money because of lost time—and sometimes can even cause complete system failures.

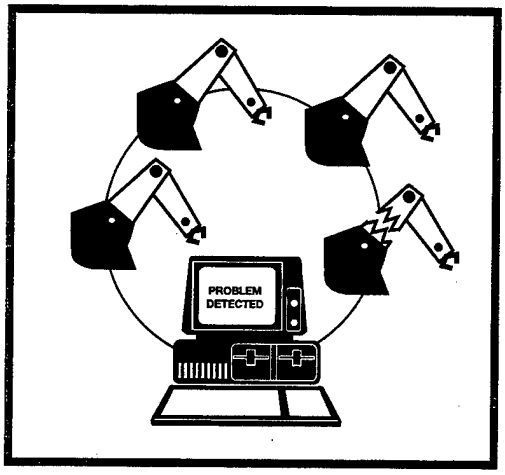
> Intelligent Automation's software decreased system failures from several a day to almost none.

Intelligent Automation, Inc., or IAI (Rockville, MD), is developing a more efficient bottom-up approach for controlling complex systems such as those used in manufacturing. The basis of its technology is BMDO SBIR-funded software originally designed for better battle management. Called autonomous agents, IAI's systems quickly react to unforeseen events by permitting moment-to-moment intelligent decision making at the equipment level.

The National Center for Manufacturing Sciences and the National Institute of Standards and Technology are providing technical support to IAI's research efforts. These organizations are pursuing autonomous agent technology to improve productivity, quality, accuracy, and speed of shop floor equipment.

In addition to optimizing overall system performance, IAI's autonomous agents can be used to allocate resources and schedule production at large factories. Decreasing system failures from several a day to almost none, IAI's system has already replaced existing computer programs to control and schedule painting in a vehicle painting facility. IAI has also teamed with Flavors Technology (Manchester, NH) to test autonomous agent technology in factory scheduling.

IAI was recently awarded an Advanced Research Projects Agency contract to develop autonomous agent technology for dependent schools overseas run by the Department of Defense. In this application, the technology can be used to search for educational materials (text, audio, and video) on the Internet quickly and efficiently. By selecting material that meets the specific needs of individual students, this project is expected to improve the quality of the children's education significantly while lowering its cost.



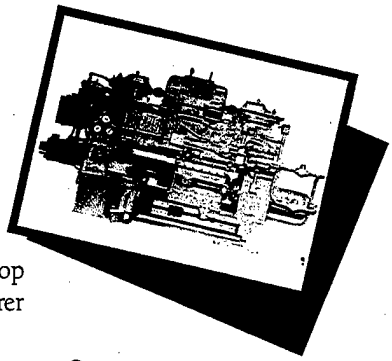
IAI's technology quickly reacts to unforeseen events by permitting moment-to-moment intelligent decisionmaking at the equipment level.

About The Technology

Autonomous agents use the science of emergent behavior (or chaos theory) to control applications whose variables linger between random and predetermined states. Today's central control systems try to predict all possible events and develop responses to each. However, small unforeseen errors or undescribed events can lead to major operation slowdowns or total system crashes. Agent-based systems offer robustness and agility by establishing intelligent decisionmaking at the local level. By making moment-to-moment control decisions at this level, autonomous agents can decrease a system's vulnerability to unforeseen problems.

IAI's initial experiments using computer simulations suggest that autonomous agents can help control the sometimes unpredictable behavior of complex systems used for military applications such as battle management. The company is currently increasing the data output of the simulations and expanding the size and variety of engagements simulated.

Neural Networks Ease Machine Distress



The National Center for Manufacturing Sciences worked with NETROLOGIC to develop a way to detect machine defects in industrial presses, such as the one pictured above.

Even with the best maintenance, heavy industrial machinery occasionally breaks down when it is operated for a long time under rugged conditions. Downtime on the typical machine shop floor ranges from 10 to 30 percent and can be very costly; failures can cost the manufacturer upwards of $150,000[4]—and can be as much as $500,000.

But manufacturers of automobiles and heavy equipment now have new insight into the symptoms of machine trouble. They know that a machine will give forewarning of its impending failure. The trick is to recognize these signs in the earliest stages so that the machine can be serviced before vital components are damaged. Early diagnosis reduces the cost of major repairs and increases the life of the machine.

General Motors and the National Center for Manufacturing Sciences joined forces with researchers at NETROLOGIC, Inc. (San Diego, CA), to develop a way to detect machine defects in industrial presses. They are using BMDO-funded algorithms to reduce the typical 10 to 30 percent downtimes to less than 5 percent.

The team is using a method called wavelet signal processing, which extracts information from signals that indicate defective machinery. Part of this development includes BMDO-funded research conducted at NETROLOGIC for neural network programming and genetic algorithms used for improved target acquisition and surveillance. Wavelet and neural network signal processing algorithms can sort out abnormal vibrations from the chaos of normal machine operation. Efforts are under way to commercialize the technology so that it can be used in related heavy industries.

NETROLOGIC USES BMDO-FUNDED NEURAL NETWORK RESEARCH TO RECOGNIZE MACHINE STRESS AND HELP PREVENT COSTLY REPAIRS AND DOWNTIME.

NETROLOGIC has consulted with General Electric in the use of neural network-based determinations for inertial weld joint quality. The two companies have also collaborated in training for the use of parallel processing. NETROLOGIC continues related research sponsored by the Department of Education, the Navy, the Air Force, the National Aeronautics and Space Administration, the Advanced Research Projects Agency, the National Center for Manufacturing Sciences, and others.

About The Technology

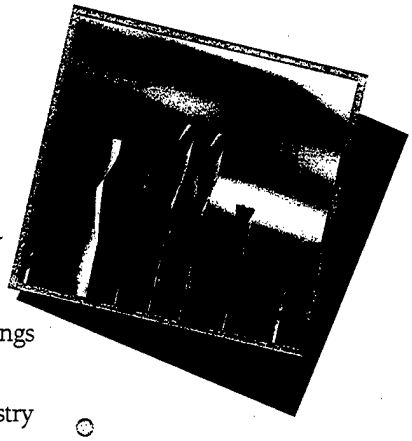
In genetic algorithms and neural processing, a system operator selects a set of variables that measure the state of a complex system. After the system's initial state parameters are processed, a new set of parameters is generated that can be used as input for a new iteration. This process is repeated until an optimal set of parameters is reached, and the system is said to have "learned" the solution. NETROLOGIC's wavelet signal processing algorithm serves as a feature extractor front end for such information processing. The algorithm is analogous to a Fourier transform; it recognizes short-lived signals, or wavelets. The wavelets are "time signatures" that occur in a nonsteady-state manner. When compared with a baseline signature, they can be used to determine the state of the machine under scrutiny.

The use of neural networks and genetic algorithms has long been associated with artificial intelligence. Other applications include data compression, pattern recognition, real-time machine diagnostics, robotics, seismic signal detection, and real-time process control.

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[4]Process Technologies Offer Strategic Benefits to American Manufacturing Community and the Nation... *FOCUS*, National Center for Manufacturing Sciences, May 1995, p. 5.

Diamond-Coated Tools Cut Through Commercial Barriers



Crystallume is leading a consortium to coat rotating tools such as drills, reamers, and end mills with its DCC® materials.

Since the mid-1980s, many entrepreneurs have dreamed of getting rich by selling new diamond products such as diamond-coated cutting tools for manufacturing and innovations for better performing microelectronics. A study conducted by Jim Russell, editor of *Diamond Depositions Science and Technology*, estimated that the total market for diamond thin-film coatings in 2020 will be at least $5 billion.

Although 2020 may seem like a long time in the future, the beginning of a commercial industry for diamond coatings is visible now. For example, Crystallume (Santa Clara, CA) raised more than $5 million in an initial public offering in 1994 to commercialize its diamond-coated products. The company received substantial early funding in diamond R&D from the BMDO SBIR program.

Crystallume's products include a new line of DCC® (diamond-coated tungsten carbide) cutting tools. These tools have been in great demand for cutting nonferrous materials—materials such as aluminum, often used to make automobiles and aircraft. Diamond cutting tools wear slowly, exhibit high lubricity, and do not heat-distort the workpiece. According to figures released by Crystallume, these products could capture as much as $450 million of the $8-billion-per-year cutting tool market.

> Crystallume has opened a new manufacturing facility and is scaling up to economically coat cutting tools with diamond.

Crystallume has overcome two major obstacles to bring its DCC® cutting tools to market. First, in a research project sponsored by the National Center for Manufacturing Sciences, the company solved the adhesion problems traditionally associated with diamond deposition on cemented carbides. Second, the company opened a new manufacturing facility, scaling up to coat cutting tools economically. This facility gives Crystallume a significant lead over competitors who cannot mass-produce diamond products.

Crystallume also markets a diamond-coated pad that spreads heat away from high-power electronic devices. And it has several products on the horizon. For example, Crystallume is leading a consortium funded by the National Institute of Standards and Technology's Advanced Technology Program to coat rotating tools such as drills, reamers, and end mills with its DCC® materials. This consortium also includes General Motors, Ford Motor Company, Boeing, Hughes Missile Systems, and Rogers Tool Works.

In addition, the company has recently coated silicon nitride ceramic ball bearings with diamond, which provides an ultrahard, low-friction, and chemically resistant surface for high-performance military and commercial machinery. And, working with a major automotive company, Crystallume is coating engine components with diamond to improve wear resistance.

About The Technology

Diamond is twice as hard as its natural competitor, boron carbide. It also has an electrical resistivity ten times that of alumina, a thermal conductivity five times that of silver, and a coefficient of friction equal to or better than that of Teflon®. Diamond is also inert to most corrosive chemicals.

Unlike natural and synthetic diamond stones, diamond films allow engineers to exploit all of its properties. Researchers have developed many different methods for producing these thin-film coatings, most of which are a variant of the original chemical vapor deposition (CVD) processes developed by Russia in the 1970s. In CVD processes, hydrocarbon gas and atomic hydrogen are mixed in a high-temperature, low-pressure reaction chamber and energized. The form of energy is what differentiates CVD processes. For instance, plasma-enhanced CVD—most often used at Crystallume—energizes a plasma local to the substrate surface using radio waves.

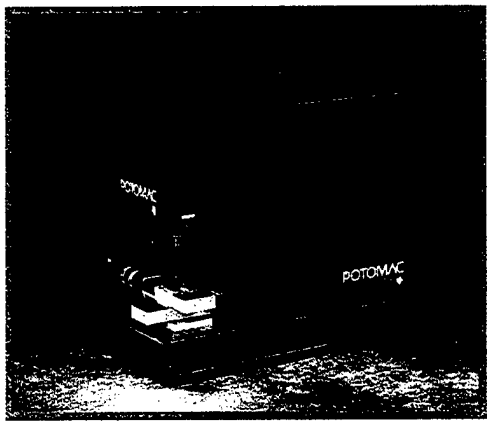
Lasers Find New Markets In Micromachining

A micrometer (or micron), one-millionth of a meter, is less than the width of a hair. Imagine having to produce microscopic structures that must be this precise, whose wires, holes, or shape cannot deviate more than one- or two-tenths of a micrometer. But, as high-tech products and their components get smaller and more detailed, that is exactly what some manufacturers must do. Micromachining, a relatively new process for manufacturing small parts, addresses this requirement. It is so accurate, it can cut and drill objects with submicron precision.

Potomac Photonics, Inc. (Lanham, MD), has entered the relatively new market for such manufacturing tools with a micromachining product called Laser MicroTools™. This tabletop workstation, based on BMDO-funded research in short-wavelength ultraviolet lasers, houses lasers with computer-integrated motion control and video imaging, and can pattern, mark, or shape a variety of materials into two- and three-dimensional structures. Since its commercial products hit the street in 1988, Potomac Photonics' commercial revenues have increased from 5 to 50 percent of its total business.

POTOMAC PHOTONICS' LASER MICROTOOLS™ HAS GREATLY CONTRIBUTED TO THE COMPANY'S COMMERCIAL SUCCESS.

Laser MicroTools™ can be used for a wide range of industrial applications. For example, they can repair semiconductors by opening shorts between conductors, so that defective computer chips can be repaired rather than scrapped. And they can drill tiny holes precisely, a task sometimes required for composite material applications. They are also useful for many medical applications, including eye surgery and tissue welding.



Laser Microtools™, pictured above, can be used to repair semiconductors and to process natural and synthetic diamond. The tabletop workstation can pattern, mark, or shape a variety of materials into two- and three-dimensional structures.

In addition, Potomac Photonics has been using the tools to process natural and synthetic diamond, forming a miniature gear in the surface of a diamond substrate. The company's ultraviolet lasers may be the key to allowing diamond-based mechanical and electronic systems to reach commercial markets. Other mechanical attempts to shape and polish diamond have been slow and cumbersome at best.

BMDO funded work in ultraviolet excimer lasers through its SBIR program to develop sensors with higher resolutions and better capabilities for processing materials. Potomac Photonics has also received related SBIR contracts from the National Science Foundation, the Air Force, and NASA.

About The Technology

In many laser applications, the shorter the wavelength the better. Shorter wavelengths provide better resolution, allowing lasers to write smaller circuits onto semiconductor materials or to detect targets better. Excimer lasers used in Laser MicroTools™ produce short-wavelength, ultraviolet beams. They usually require large power sources and offer low repetition rates, both of which are constraining to production environments.

Instead of pumping the laser with electrical pulses, a technology that requires large power sources, Potomac Photonics' lasers are pumped with electrodeless microwave discharges. This pumping method saves space not only by using a smaller power supply but also by requiring less lasing gas for sustained operations. Potomac Photonics' excimer lasers also provide repetition rates of up to 2,000 hertz, versus 100 to 500 hertz for other excimer lasers, providing faster processing and allowing the lasers to machine three-dimensional structures.

R&D Targeted To Lower Costs For Semiconductor Manufacturers

Manufacturers in the microelectronics and optical communications industries are constantly looking for ways to improve their high-speed, high-performance systems. With fierce competition both domestically and abroad, the manufacturers not only require high-tech components and materials, but also affordable processes to cheaply and safely mass-produce their new approaches.

Jet Process Corporation (New Haven, CT) has developed a simple, low-cost, and environmentally friendly process called Jet Vapor Deposition, or JVD™, that can deposit high-quality coatings of many materials on almost any substrate. This enabling technology will allow manufacturers in the microelectronics and optical communications industries to mass-produce new generations of high-speed equipment. Such uses for JVD™ are transforming Jet Process from a custom fabricator of thin-film materials to a major player in the materials manufacturing business.

Using JVD™, Jet Process Corporation has teamed with Olin Corporation and General Motors to develop an environmentally benign alternative to electroplating.

"In the short term," explains Jerry Schmidt, president of the company, "Jet Process is marketing custom JVD™ 'toll coating' manufacturing services to companies such as AT&T. Jet Process plans to further develop and market the JVD™ process through joint venture and licensing agreements with major U.S. manufacturing companies."

These plans have, in part, already begun to come to fruition. Using JVD™, Jet Process is working on a cost-shared project with Olin Corporation and General Motors' Packard Electric Division to develop an environmentally benign alternative to electroplating for electronics manufacturing. This project is sponsored by the Advanced Research Projects Agency.

Several Government R&D contracts, including two BMDO SBIR contracts to develop advanced semiconductor and optical materials, have helped the company. With BMDO funding, Jet Process has developed a low-cost way to make nonlinear optical materials—materials expected to form the foundation of emerging high-speed optical switching and information processing systems. Nonlinear optical materials react with different optical effects when subjected to different intensities of light, a capability that conventional optical materials lack. But they are very costly and difficult to produce in quantity. Jet Process' JVD™ technology can handle the complexity of making these components affordably and in mass quantities.



JVD™ can deposit many types of material coatings on almost any substrate. It features, among other benefits, relatively low equipment and operating costs and high deposition rates.

The company is also using JVD™ to make silicon nitride films for insulators, used in many semiconductor devices. Silicon nitride is better than the dominant insulator, silicon dioxide, because it can provide twice the barrier to current flow, allowing manufacturers to use thinner films and pack more circuitry into less area. But despite its advantages, silicon nitride has not been widely used because it is more difficult than silicon dioxide to deposit on silicon-based devices. Now Jet Process' JVD™ is being targeted to solve this problem for the microelectronics industry. The company has also used JVD™ to make coatings that have improved the performance of batteries, jet engine components, and composite material (just to name a few).

About The Technology

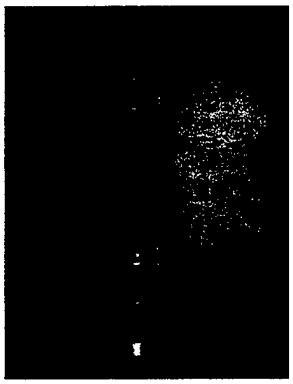
The JVD™ process uses sonic jets of high-purity inert gas, operating at ambient temperatures and in "low vacuum," to transport the coating vapor onto a variety of substrates, resulting in high-quality thin films. The patented process features lower equipment and operating costs than other deposition methods and pollution-free operation. It has high deposition rates (up to 1 micrometer per minute over a 1,000 cm^2), fast turnaround times, and a 90 percent material conversion efficiency.

Ionwerks' Measure Of Success Is Better Materials

Ionwerks (Houston, TX) is selling three new products that fill an important need in materials production. Its products, which monitor the growth of thin films, address a small market mainly represented by research institutions. Researchers using Ionwerks' products will be able to learn more about wide-bandgap materials such as diamond, gallium nitride, and silicon carbide used in modern electronics and electro-optical systems. They can then pass this information on to manufacturers so that new products using these materials can be mass-produced.

> IONWERKS' NEW PRODUCTS WILL ENABLE RESEARCHERS TO MAKE A NEW CLASS OF MATERIALS THAT CAN BE USED IN EVERYTHING FROM JET ENGINES TO ELECTRONICS.

The exceptional properties of wide-bandgap materials will allow manufacturers to make new commercial products in such areas as machine tools, electronics, optics, and even jet engine components. For example, the materials can be used to make more durable cutting tools, lower friction machinery, better corrosion protection coatings, and better heat dissipation designs for electronic components. Ionwerks' products will provide the research tools instrumental in developing processes to make these materials.



Pictured above is Ionwerks' analysis tool that can be used to study the growth of wide bandgap materials.

But before wide-bandgap electronics can be commercialized, researchers need to learn more about how these materials grow. BMDO—interested in wide-bandgap electronics to meet the high-power, high-frequency, high-temperature electronic system demands of ballistic missile defense—awarded two SBIR contracts to Ionwerks to develop advanced monitoring equipment.

Several collaborative efforts illustrate payoffs for Ionwerks' innovations. For instance, IBM Yorktown Heights has used one of Ionwerks' products—an analysis tool based on mass spectroscopy of recoiled ions (MSRI)—to understand in detail the thin-film growth mechanisms of several wide-bandgap materials; the team's findings have allowed IBM to produce some of the highest quality films to date. Ionwerks has also completed a 1-year cooperative research and development agreement with Argonne National Laboratory to study MSRI's process control applications. Because of this project, a major aerospace company is interested in using Ionwerks' MSRI to detect impurities in thermal shock barriers during protective coating deposition of jet engine turbine blades. Argonne National Laboratory and SI Diamond Technology, Inc. are also using Ionwerks' MSRI to monitor the growth of diamond thin films.

Since its first sale of hardware and electronics for MSRI in 1993, Ionwerks has released two more products: a time-to-digital converter (TDC) and a fast x-y detector. Both instruments can be used in many charged particle detection schemes. The TDC records time-of-flight measurements of a particle's kinetic energy, and the fast x-y detector quickly and accurately measures a particle's point of impact. These two devices together can measure position and time at speeds and accuracies previously unobtainable. They can also be used for laser radar sensing and imaging devices.

About The Technology

Mass spectroscopy of recoiled ions measures the elemental composition of thin-film surfaces as they grow. This feature—which results from MSRI's ability to operate at typical wide-bandgap material growth conditions (i.e., pressures around 10 milliTorr) and not at the high-vacuum conditions (around 10^{-6} Torr) required by other techniques—enables researchers to monitor a film's properties layer by layer as it grows. MSRI can also distinguish among ions of similar mass while causing almost no surface damage and can analyze dopant concentrations during and after growth. Ionwerks' other products also offer many advantages. The TDC provides 10 times better resolution and 10 times faster readout rates than older technologies. It also costs 15 percent less and features four channels (versus one in others). The fast x-y detector can measure an ion's point of impact at a resolution of less than 0.5 mm and with a readout rate 100 times faster than competing technology.

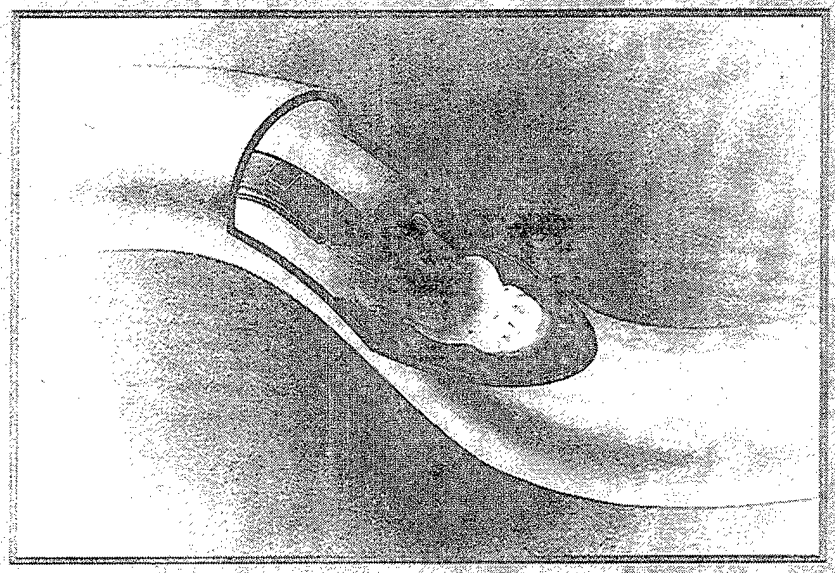
With an aging, cost-conscious, and health-minded population, the United States has become increasingly aware of medical issues. Advanced technology can address some of these issues, revolutionizing many medical procedures and enhancing the quality of medical products and services. Procedures that once were complex, painful, or risky are now, or will soon be, performed by innovative noninvasive or minimally invasive techniques. For example, advanced sensors will allow glucose levels in blood to be monitored without puncturing the skin, offering better quality of life for millions of diabetics. Sophisticated technology will offer physicians better, more accurate tools, potentially saving lives and improving the quality and efficiency of patient care. Also, such technologies often reduce or eliminate the need for hospital care, thereby reducing associated costs.

Today's market. The United States is the world leader in producing medical devices, accounting for 41 percent of the total worldwide market. The medical industry relies heavily on innovative breakthroughs provided by the 11,000 companies—most of which are small businesses—that contribute to its products. U.S. companies have developed more than 80 percent of all commercialized medical devices produced over the past 40 years. In 1993, the worldwide market for medical devices was roughly $93 billion.[1] The customers—hospitals, private practitioners, health maintenance organizations, and the patients themselves—have, until recently, been limited to traditional technologies used for years; however, innovative technologies with cost-saving implications are beginning to change this picture.

Tomorrow's opportunity. To protect the Nation and its troops overseas, BMDO has funded the development of many highly advanced technologies such as computer algorithms, lasers, and optics to detect and eliminate an enemy's incoming missiles. But the same technology can be used to protect the Nation from another enemy—the threat of disease. Many organizations with BMDO-funded R&D are applying their findings to the medical arena, making new breakthroughs in cardiac disease, cancer, and diabetes. The following section describes six of these innovations.

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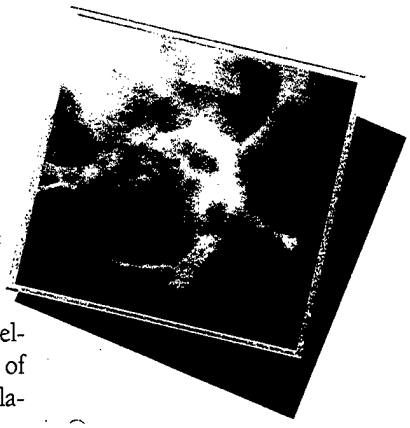
[1] *Industry Surveys*, Standard & Poor's, September 7, 1995, p. H-43.



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MEDICAL TECHNOLOGIES

X-Ray Detector For Cancer May Save Lives



Hughes Aircraft company and NOVA R&D are developing a device to detect breast cancer early, potentially saving thousands of lives.

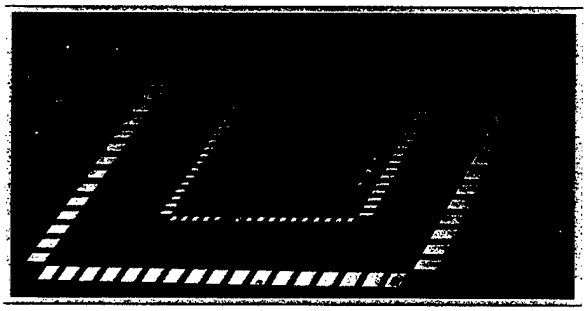
This year, 182,000 American women will be diagnosed with breast cancer; 46,000 will die from the disease. Many of these lives might have been saved had the cancer been detected sooner.[2] In fact, with early detection, 5-year survival rates are estimated at 96 percent. Unfortunately, early warning signs are missed more than half the time. Many women who develop breast cancer had received clean bills of health on previous mammograms; in 60 percent of these cases, cancer indications were visible in earlier tests but went undetected using the relatively low-contrast images available.

NOVA R&D, Inc. (Riverside, CA), and Hughes Aircraft Company (El Segundo, CA) have found a way to solve this problem. The team has come up with an advanced digital mammography unit that could help doctors spot life-threatening cancer early enough to save thousands of lives.

Using BMDO-funded R&D, NOVA is developing a mammography system through the National Institutes of Health.

This technology is based on BMDO funding at Hughes for work on silicon pixel x-ray detectors (SiPD). It was initially developed with military needs in mind, such as the Sensor Experiment Evaluation and Review (SEER), Precursor Above the Horizon Sensor (PATHS), and Hybrids With Advanced Yield for Surveillance (HYWAYS) programs.

NOVA has enhanced an SiPD device and is developing the mammography system with funding from a National Institutes of Health SBIR contract. In this system, researchers are mounting a linear detector array on an accurate swing arm so the array can be scanned under the patient's breast. Among other improvements, NOVA expects its system will be able to display images with greater contrast and finer detail than other methods of breast examination. It is also expected to expose patients to less radiation.



The silicon pixel device, pictured above, is the basis for the digital mammography unit. This device is being enhanced so that images can be displayed with greater contrast and finer detail than conventional mammography.

The technology has medical applications in addition to mammography. For example, it can be used for tomographic animal studies, bone densitometry, and panoramic dental x-rays. In fact, this technology looks so promising that Fischer Imaging (Denver, CO) has already expressed interest in helping to commercialize it once the project is completed.

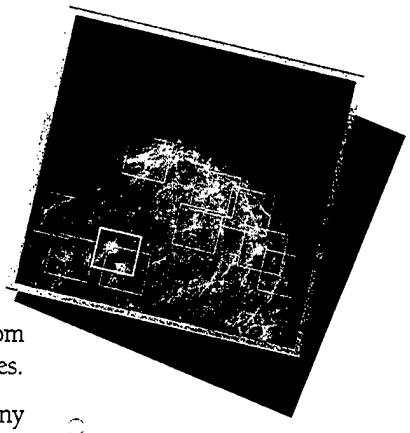
About The Technology

The technology behind NOVA's SiPD device consists of two sections: a two-dimensional silicon p-doped/intrinsic/n-doped (PIN) diode array and a front-end readout electronics chip with time-delayed integration (TDI) charge-coupled device (CCD) function. This function, developed by NOVA, allows the system to tolerate random dead pixels in the array that may occur before or after fabrication. The sections are designed with matching pixel geometry and are electrically connected using an indium bump bonding technique. This allows each diode to be directly connected to its readout electronics and allows fabrication of small capacitance and low noise detectors.

Though Hughes holds a patent on the original technology, NOVA has enhanced it for medical imaging. In developing its own readout system, NOVA made the pixel array thicker and added the time-delayed integration function, resulting in a technology that promises to detect the warning signs of breast cancer before it is too late.

[2] *Cancer Facts* (Factsheet), American Cancer Society, 1994.

Pattern Recognition Speeds Detection Of Breast Cancer



Bold white boxes indicate possible abnormalities in this mammogram.

Costs for mammography services, estimated in 1992 to be as much as $3 billion in the United States[3], account for a large portion of medical expenses. When adapted to medical use, BMDO-funded research in pattern recognition technology can reduce these mammography costs by speeding analysis and diagnosis. This technology may also reduce the number of deaths from breast cancer, since it can detect the disease earlier than conventional mammography techniques.

Rose Health Enterprises (Denver, CO) and Lockheed Martin (Denver, CO) formed a company called MedDetect, LLC, to use such BMDO-funded technology to analyze medical images. MedDetect's optical system is projected to quickly identify 75 percent of screening mammograms that are negative, allowing doctors more time to examine potential cancer cases closely.

MEDDETECT'S SYSTEM IS PROJECTED TO QUICKLY IDENTIFY 75 PERCENT OF SCREENING MAMMOGRAMS THAT ARE NEGATIVE, GIVING DOCTORS MORE TIME TO EXAMINE POTENTIAL CANCER CASES CLOSELY.

In addition, the technology makes screening a more powerful and accurate tool by automatically identifying abnormal image attributes. In preliminary tests on an archive of mammographic images, it has already detected a cancerous breast lesion, that, using conventional mammography, did not appear for another year.

MedDetect's initial work in the medical arena has been focused on integrating optical processors with complex algorithms to improve mammographic images. But the company expects to use these methods in other medical applications as well, such as to improve cancer detection processes in chest x-rays and Pap smears. It is using much of the technology, including target scene generation software and optical components for rapid data processing, that Lockheed Martin developed with BMDO funding for advanced target acquisition and recognition.

MedDetect's optical system will be compatible with "filmless" digital mammography, which several companies and research groups, such as Fischer Imaging (Denver, CO), NOVA R&D (Riverside, CA), and ThermoTrex (San Diego, CA) are developing. Using MedDetect's technology, digital x-ray images can be analyzed in less than a minute. The images can then be transmitted to another radiologist for a second opinion. In addition, digitally storing images at a central location allows physicians to quickly access records for baseline image analysis and comparison.

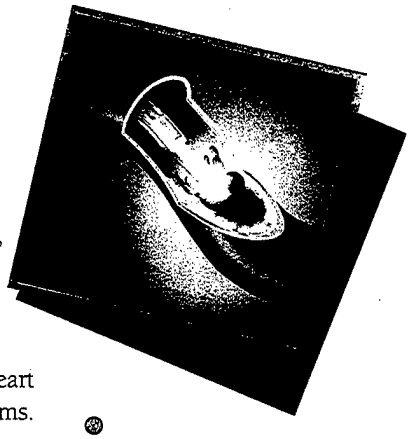
Both Rose and Lockheed Martin are providing seed money for MedDetect, with plans to raise additional private capital and have a prototype available within 18 to 24 months. Technology improvements achieved by MedDetect will also be returned to Lockheed Martin's defense technologies.

About The Technology

MedDetect's system is a hybrid of optical and digital processing. An optical correlator uses lenses and a low-power laser to examine the mammogram. The optical correlator, with programmable spatial light modulators and Fourier transform lens pairs, uses photons instead of electrons to perform the calculations to detect an abnormal feature. This information is then transmitted to a computer that uses neural network software to "learn" the specific attributes of breast abnormalities. The learned information is stored and applied to new images.

[3]How Much Preventive Care Can We Afford?...K. Terry; *Medical Economics*, August 23, 1993, p. 124.

Lasers Target Blood Clots In New Method



Laser thrombolysis, pictured above, destroys blood clots using a laser beam. This method presents cost, recovery time, and safety advantages over methods such as bypass surgery.

Coronary heart disease (CHD) is the leading cause of illness and death in the United States, with an estimated 52 million adults at moderate to high risk. The American Heart Association found that medical costs associated with treating this disease amount to $56.3 billion per year; lost productivity adds $8 billion to this cost.

CHD can lead to blood clots in coronary arteries, which impede blood flow and can cause heart attacks. While treatments are available to get rid of blood clots, they are not without problems. Therefore, medical researchers are seeking safer, easier, and cheaper ways to eliminate clots.

One approach is a technology called laser thrombolysis, which is being developed in a cooperative research and development agreement (CRADA) at Los Alamos National Laboratory, or LANL. The laboratory is working with medical experts from all over the Nation, including Palomar Medical Technologies (Beverly, MA), Oregon Health Sciences University (Portland, OR), and St. Vincent's Hospital (Portland, OR). Initiated in early 1995, the U.S. Department of Energy-funded CRADA is scheduled for 3 years of development.

In laser thrombolysis, a laser beam is delivered through an optical catheter, usually inserted in the femoral artery (in the thigh) and threaded into the affected artery of the heart, where a pulsed laser beam destroys the clot. Several years ago, BMDO funded related theoretical laser studies in laser-matter coupling at LANL, which were applied to laser pulses on biological tissue and helped provide insight into this medical technology.

The group is currently conducting Food and Drug Administration (FDA)-sponsored testing, a year-long process that involves 60 heart attack patients at St. Vincent's Hospital, Washington Hospital Center (Washington, DC), Scripps Clinic (La Jolla, CA), and Methodist Hospital (Lubbock, TX). Once developed, laser thrombolysis could annually treat more than 100,000 patients; but before this happens, the method needs to be further refined and FDA approved.

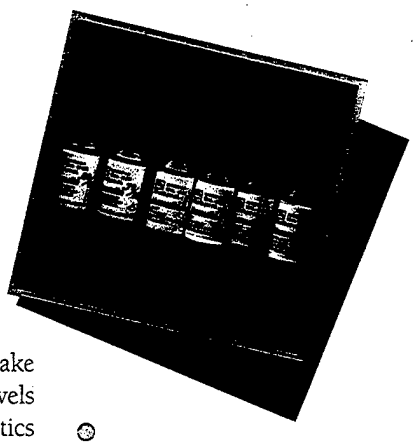
Using BMDO-funded R&D, the group is conducting FDA-sponsored testing to eliminate blood clots, a process that involves 60 heart attack patients.

Research findings indicate that laser technology has several advantages over other methods. For example, depending on the patient, laser thrombolysis may reduce the need for injections of clot-busting drugs such as streptokinase and tissue plasminogen activator (tPA), which enzymatically dissolve clots. Suitable for only about 40 to 70 percent of potential patients, these drugs sometimes cause allergic reactions and hemorrhaging. Laser thrombolysis has not been shown to cause such problems. In addition, since the thrombolysis technique is more selective in destroying the clot, it does not present problems associated with current angioplasty or other treatments, which can damage the artery walls. It also offers cost, recovery time, and safety advantages over bypass surgery, in which surgeons must replace arteries.

About The Technology

In laser thrombolysis, a laser beam is delivered to a blood clot through a fluid-core optical catheter. The yellow-green laser pulse delivered in the catheter is absorbed much more efficiently in a blood clot than in the surrounding arterial wall, which means that the clot can be heated and vaporized without damaging adjacent structures. The platelets in the clot are also destroyed, reducing the chance of a new clot forming from the released debris. Avoiding damage to the arterial wall is also important in the prevention of re-stenosis, or renewed narrowing. The laser thrombolysis procedure is monitored by radiography similar to more conventional angioplasty methods. Fortunately, because the x-ray-opaque dye used in these procedures is transparent to the laser beam's wavelength, the laser method is compatible with existing catheterization protocols.

Blood Glucose Monitor Eliminates Painful Testing



Roughly 15 million people in the United States suffer from diabetes.[4] In the realm of diseases, it is the third biggest killer and can lead to blindness, kidney failure, cardiovascular disease, and serious infection.

Therefore, it is essential for diabetics to maintain good health, which often requires them to take insulin every day. Today, about 2.5 million patients must carefully monitor blood glucose levels to determine the efficacy of the insulin. Unfortunately, current technology dictates that diabetics stick their fingers with a needle a few times each day to test their blood. This process is both painful and expensive—roughly $800 million is spent on home glucose kits each year.[5]

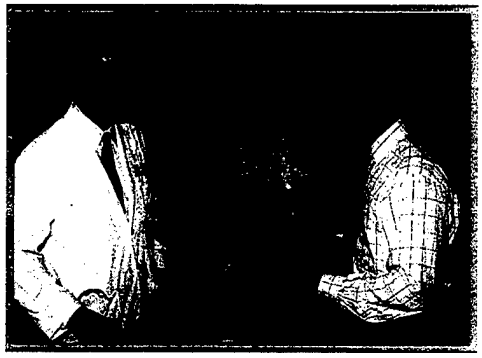
Roughly 2.5 million patients must monitor blood glucose levels to determine the efficacy of the insulin, daily sticking their fingers with a needle to test blood. Rio Grande Medical Technologies' device offers a noninvasive approach to this testing.

> Noninvasive blood glucose monitors will be a boon to the health of diabetic patients.

As a noninvasive, needle-free alternative, Rio Grande Medical Technologies, Inc. (Albuquerque, NM), is developing a glucose monitor that reads blood glucose levels using spectral analysis of a near-infrared (IR) beam. This innovation presents a painless and waste-free way to monitor blood glucose levels. If the cost and size can be reduced this technology may well extend glucose monitoring services to many more diabetics with less stringent insulin requirements.

The portable blood analyzer can also be used in law enforcement and emergency medicine, and for critical care patients and those undergoing general anesthesia. Forward medical care on the battlefield may be another use.

Rio Grande was founded expressly to commercialize this technology, collaborating extensively with Sandia National Laboratories, or SNL (Albuquerque, NM), and the University of New Mexico School of Medicine. BMDO-sponsored research at SNL led to the multivariate analysis software used in the monitor's spectral analyzer—R&D originally designed for space-based imaging and nondestructive analysis.



Rio Grande is aggressively pursuing the technology development and product engineering with strong contributions from a large U.S. health care company and funding from the Advanced Research Projects Agency Technology Reinvestment Project. One of the challenges now is to reduce the size of the monitor.

Rio Grande was founded expressly to commercialize this technology. Pictured above is the device, which uses spectral analysis of a near infrared beam.

About The Technology

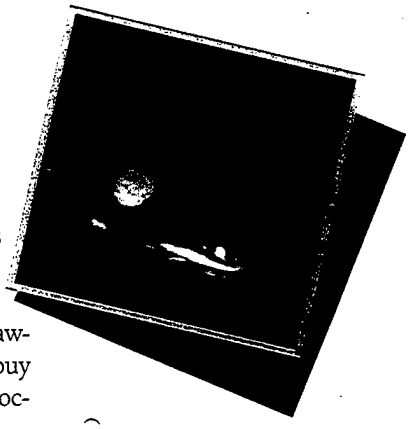
To operate the blood monitor, a near-IR light beam is passed through the finger, and the spectral components of the emergent beam are measured using statistical computing and spectroscopic techniques. The level of glucose is determined by how much light at a particular wavelength is absorbed by the glucose compared with how much light strikes the photodetector. The monitor is nearly as accurate as present systems, which rely on visual or digital reading of color-coded strips compared with a blood sample. It eliminates finger-sticking, and can also provide a way to quickly examine trends in blood glucose levels. Near-IR spectral analyzers can also be used to determine blood alcohol levels, as well as carbon dioxide, bicarbonate ion, and oxygen content of the blood.

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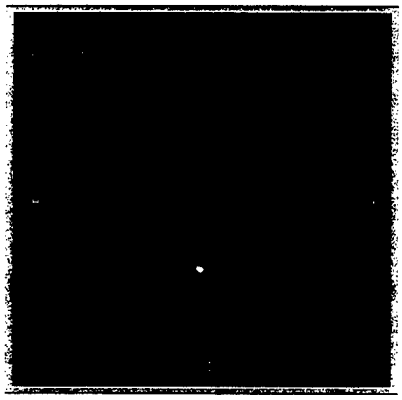
[4] *Draft Testimony to House Subcommittees on Basic Research and Technology,* Tom Fortin; Rio Grande Medical Technologies, Inc., presented June 27, 1995.

[5] Infrared Technology May Aid Diabetics, *Aviation Week & Space Technology*, August 23, 1993, p. 65.

Superconductors Reduce Time For MRIs



Pictured above is a magnetic resonance image using STI's superconducting coil. Pictured below is the same image obtained using conventional copper coils.



Magnetic resonance imaging has become almost as routine as the x-ray. MRI enables doctors to detect brain tumors, examine torn ligaments, and observe other soft tissues without having to open up the patient. But these imagers are not problem free. For example, patients must lie very still inside a costly and noisy capsule for about 40 minutes, which is a major drawback for children and people with claustrophobia—not to mention the hospitals that must buy these machines. And while "open" MRIs are available, they often cannot show the detail that doctors need for making crucial decisions.

To combat these problems, researchers at Superconductor Technologies, Inc., or STI (Santa Barbara, CA), are speeding up MRIs and improving their images using a high-temperature superconducting coil called the SuperSensor™ coil. Replacing copper coils used in open MRIs, STI's technology can produce images comparable to those of conventional MRIs in about a quarter of the time. And if doctors use an MRI with the SuperSensor™ coil for the traditional 40 minute time period, images with 50 to 150 percent better resolution can be produced.

> IN 10 MINUTES, OPEN-ACCESS MRIS USING THE SUPERSENSOR™ COIL WILL PRODUCE IMAGES COMPARABLE TO THOSE OF CONVENTIONAL MRIS.

These benefits can occur in an open system, eliminating the cost and claustrophobia problems of closed systems. The Food and Drug Administration has approved one of STI's coils; and while approval is needed for two more to complete a system, the company has already overcome a major hurdle in entering the medical industry.

Through its SBIR program in high-temperature superconductor (HTS) thin films, BMDO funded the baseline developments that led to the SuperSensor™ coil. Since then, the National Institutes of Health has funded research to develop and reduce the costs of such coils for MRI applications. STI is interested in partnerships to bring this technology to market.

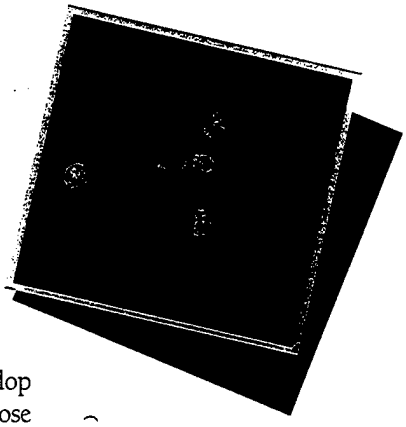
STI's commercialization of BMDO-funded R&D has also spread into other areas. In fact, the company has an entire product line called *Micro*Loss® for microwave communications, which includes superconducting thin films, superconducting microwave resonators, superconducting custom design kits, and hi-Q superconducting microwave resonators (2 to 35 gigahertz). The company's technology is also preventing dropped cellular telephone calls by incorporating HTS thin-film components into cellular telephone base station receivers, making them more sensitive and accurate in handling calls. STI is filling orders from three major cellular communications companies for HTS receiver filters.

About The Technology

One of the hurdles in manufacturing an HTS thin film is finding a substrate compatible with the superconducting material. The substrate should support the HTS material and be a good electrical insulator. In addition, the crystal lattice of the substrate should align closely with the lattice of the crystallized HTS material. This alignment allows maximum flow of current through the thin film.

To meet these requirements, STI has developed a thallium barium calcium copper oxide (TBCCO) superconducting thin film deposited on a lanthanum aluminate ($LaAlO_3$) substrate. TBCCO is advantageous because it will superconduct up to the relatively high temperature of 100 K (–279°F). $LaAlO_3$, in turn, has a high dielectric constant (about 24) and a low loss tangent (3×10^{-5}), both of which indicate the material's ability to electrically insulate. The substrate's good insulating qualities make the superconducting system highly efficient.

Tunable Filters Adjust To Many Wavelengths



Ciencia's AOTF technology helps visualize fluorescence activity in living cells.

As health care moves into the 21st century, innovations in optical technologies are expected to change the way doctors and other medical personnel do their jobs, both in the operating room and on the examination table. Such advances will, for example, allow doctors to analyze blood without drawing a drop.

Researchers at Ciencia, Inc. (East Hartford, CT), have used BMDO-funded technology to develop optical filters that may contribute to this change, vastly improving the way doctors diagnose patients and analyze blood and tissue. Their patented polymer-based acousto-optic tunable filters (AOTFs), originally developed for defense, are being used in rugged, portable, low-cost spectrometers for the medical community.

Although several companies have developed AOTFs, Ciencia's innovative approach makes the manufacture of these devices easier and more reliable, bringing them much closer to commercial use. To move its spectrometers to market, Ciencia has been funded by Connecticut Innovations, Inc., a State-funded commercialization organization.

Ciencia staff began work on AOTFs while at Scientific Research Associates, Inc. (Glastonbury, CT), for the BMDO SBIR program. They later spun off and formed Ciencia, developing AOTF-based ultraviolet sensors for military target identification and surveillance systems. Ciencia has since received BMDO SBIR funding for further research and development of AOTF technology.

> CIENCIA'S RUGGED, PORTABLE SPECTROMETERS CAN IMPROVE THE WAY THE MEDICAL COMMUNITY DIAGNOSES PATIENTS AND ANALYZES BLOOD AND TISSUE.

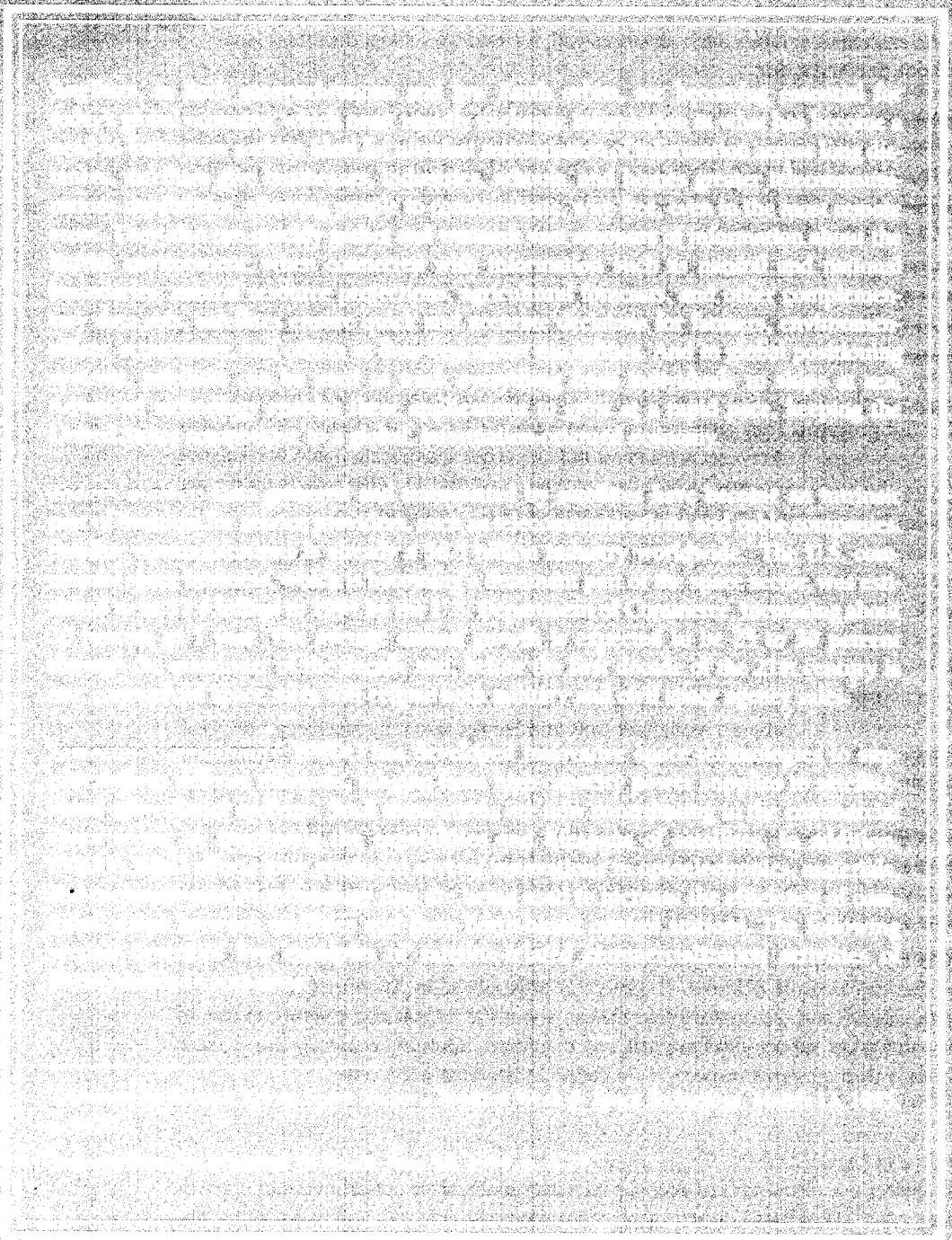
One of the products Ciencia is developing with funding from the National Institute of Mental Health is a portable cancer-detecting spectrometer. Able to analyze tissue in vivo, this product could be key in optical biopsy systems, which use light absorption measurements to detect cancer—a painless alternative to surgical biopsies. Ciencia's Raman spectrometer will allow doctors to distinguish between malignant cells and benign tissue by analyzing biological fluids and examining their fluorescence and Raman signatures. Researchers at the company are also developing filters that can determine cell contents, with future plans for blood flow imaging.

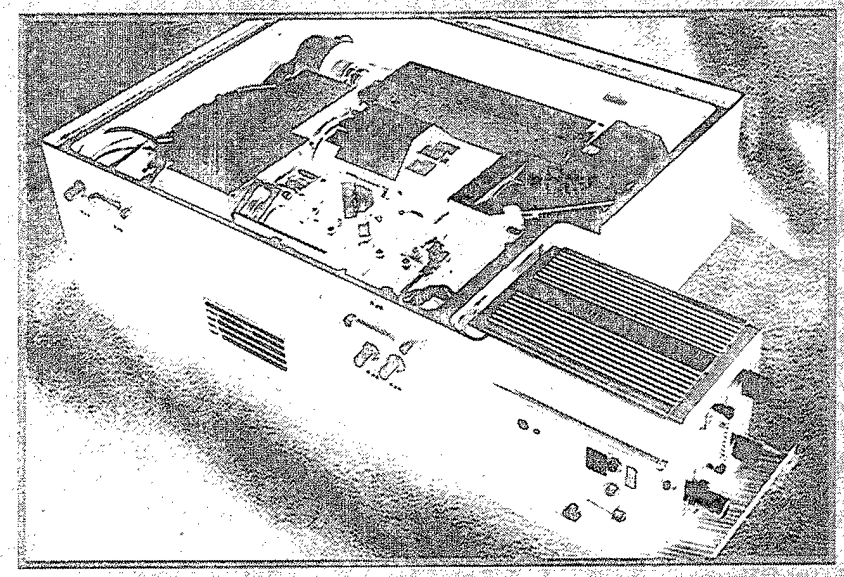
In addition to medical applications, Ciencia is pursuing markets for environmental technologies, chemical process control, and remote sensing. For example, working with Sunkist Growers, Inc., Ciencia has completed the first phase of an optical nondestructive testing system that detects molds and other contaminants in citrus fruit.

The company is also planning a collaboration with Woods Hole Marine Biology Laboratory to design sensors that can measure chlorophyll content in phytoplankton. Such measurements can yield valuable qualitative and quantitative information about the habitat and population size of tuna, dolphins, and other surface-dwelling fish and mammals. Scientists currently assess these populations visually through aerial inspection—a method somewhat imprecise.

About The Technology

Acousto-optic devices use ultrasound to alter the refractive index of an optical medium, typically a crystal. Ciencia's AOTF is based on an organic amorphous material rather than the more conventional inorganic crystals. The organics are less expensive to make than the crystals, allow for uniformity and quality control during the manufacturing process, and permit independent control of bandpass and bandwidth. Unlike an ordinary monochromator, the AOTF can be tuned electronically, so it has no moving parts. By sweeping the ultrasonic tuning frequency, the polymeric device produces spectrally resolved images.

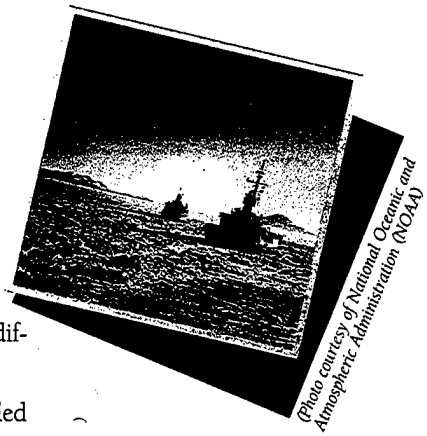




Essex Corporation,
page 74

SATELLITES

Processor Enables More Easily Obtainable Satellite Imagery



(Photo courtesy of National Oceanic and Atmospheric Administration (NOAA))

Pursuing satellite applications, Essex has cited uses such as iceberg detection, quickly and precisely informing local monitoring stations about icebergs.

Data from radar satellite images are usually collected, stored, and processed at one central location, where they are then converted to a standard image product. Organizations that want information must contact the data bank, which forwards these products to them. However, end users who need to obtain tailored information or nonstandard products often find the process difficult and time-consuming.

Essex Corporation (Columbia, MD) has developed a high-speed optoelectronic processor called ImSyn™, which will allow organizations to use their own workstations to tap into and interpret satellite data. By using these processors at their workstations, groups can obtain the specific data they need without going through a central station. In addition, when installed directly on a satellite, Essex's product could allow satellites to transmit 10 times more information stored onboard than is currently possible. ImSyn™ is expected to be on the market in 1996.

> ESSEX'S IMSYN™ WILL ALLOW LARGE COMPANIES AND ORGANIZATIONS TO USE THEIR OWN WORKSTATIONS TO TAP INTO AND INTERPRET SATELLITE DATA.

Pursuing satellite applications, Essex has cited uses such as iceberg detection. The processor could quickly and precisely inform local monitoring stations about icebergs in the area. The processor would give sea captains the ability to access current information very quickly, which is essential since icebergs drift, are often hidden by cloudy weather, and present danger to unsuspecting ships. While satellites currently monitor iceberg activity, only selected, small areas are processed in real time.

ImSyn™ also addresses limitations associated with current optoelectronic processors, which require data to fit into rigid x-y coordinates for processing. In a less-than-perfect world, most data do not fall on the crosshair zero reference but rather at the limits of an image, and normally require significant computation to resolve accurately. With its flexible data-formatting capabilities, ImSyn™ can look into this "gray area" and quickly and accurately reference it, thereby giving the user a more precise presentation of the data. This capability makes the Essex processor useful in applications such as medicine where extreme accuracy in imaging is critical.



ImSyn™, shown above, can form images from a wide range of sensor data. It uses very little power and requires no special cooling.

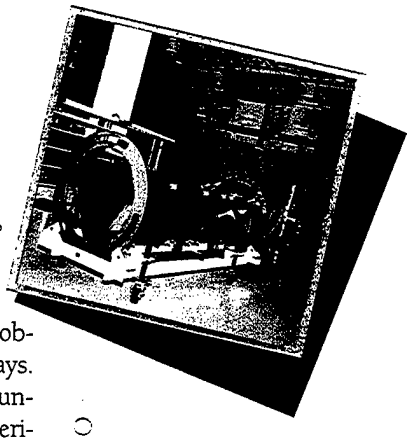
For example, ImSyn™ could be used as a component of magnetic resonance imaging (MRI) systems, greatly improving images while increasing processor speed. Measuring 1.5 cubic feet and weighing only 50 pounds, it could also reduce the size and weight of the current refrigerator-sized MRI processors. The device may also be used to diagnose tissue or specimen samples in real time where pattern recognition—such as defining cancer cells—could mean the difference between life and death in early detection of disease.

Essex Corp. is discussing applications with the medical community and has begun negotiations with other interested parties, including some in the international arena. The processors are programmable, so one workstation can be adapted to many applications—for example, allowing one system to support an entire radiology department.

About The Technology

ImSyn™ can form images from a wide range of sensor data. It uses very little power and requires no special cooling even though it processes at supercomputing speeds. It incorporates digital electronics integrated with an optical module and outputs a digital product. The digital electronics allow ImSyn™ to offer precise control of signal input, noiseless integration of detector output, and flexible formatting of input data and digital output. The processor's optical module matches the sensor's coordinate systems using naturally parallel transforms to process images quickly. Because it does not depend on fixed algorithms for image formation, it rapidly integrates final results into complex digital image output.

Damping Device Is Being Tested For Commercial Satellites



The IRIDIUM™/℠ concept consists of about 75 small communications satellites in low Earth orbit. Lockheed-Martin is testing prototypes of Taylor Devices' damper on the constellation's first satellite.

While people are immediately inclined to blame the cable company for that annoying "snow" on their television screens, the real culprit could be the satellite that sends programs to the ground stations. These expensive orbiting signal relay systems can sometimes develop onboard electronic or mechanical problems. Satellites are particularly vulnerable to these problems as they reach final orbit and deploy antenna and solar arrays. If the mechanical systems fail, there usually is no backup or redundant system, and the multi-million dollar satellite could be in serious trouble.

TAYLOR DEVICES IS NOW BUILDING PROTOTYPES OF ITS INNOVATIVE DAMPER FOR LOCKHEED-MARTIN, WHICH WILL USE THE DEVICES TO DEPLOY SOLAR PANELS ON IRIDIUM ™/℠ SATELLITES.

Taylor Devices (North Tonawanda, NY) has developed a strut that maintains optical alignments and protects electronic parts from shock and vibration during launch and deployment of satellite systems. The strut also maintains the "clean" environment required by a space-based sensor. Funded by BMDO under subcontract to the Massachusetts Institute of Technology (MIT), the damper assembly in the strut was originally developed as part of an active suspension system for a "crash-proof" telescope motion pad that had to maintain fine alignment during telescope repositioning. Now the strut has important uses in the growing number of communications and remote sensing satellites.

For example, Taylor is now building prototypes of its patented, frictionless hermetic damper for Lockheed-Martin, to be used to deploy solar panels on the IRIDIUM™/℠ communications satellite constellation. The IRIDIUM™/℠ concept, one of several constellations of satellites being planned for launch before the year 2000, will consist of about 75 small communications satellites in low Earth orbit. Lockheed-Martin is testing prototypes of the Taylor Devices damper with the constellation's first IRIDIUM™/℠ satellites, now in the early phases of production.

If vibration occurs while satellite solar panels are being deployed or repositioned to stay in solar alignment, it can upset critical electronic or optical systems onboard the spacecraft. Taylor's strut protects against these problems.

In addition, the hermetic seal of the strut offers advantages critical to space applications. A leak from a nonhermetically sealed strut in space can cause two types of damage. A leak (known as "outgassing," since most volatile compounds rapidly turn into a very fine gas in the vacuum of space) forms a cloud around the spacecraft, contaminating optics and electronics. In addition, the pressure differential between the pressurized part of the leak and the near vacuum of space actually results in a force that may be enough to affect the spacecraft's attitude, complicating both control and accuracy of transmitted signals.

Repairing an orbiting communications satellite is virtually impossible, unless it is close enough to the Earth to be reached by the space shuttle. Even if rescue is possible, considerable time can elapse before the Shuttle astronauts arrive to attempt a repair. Costs of such rescue missions rapidly escalate to tens of millions of dollars, not counting loss of income from the lucrative communications traffic.



Taylor Devices' strut protects against vibration, which can occur while satellite solar panels are being deployed or repositioned to stay in solar alignment. The device's hermetic seal protects the optics and electronics from outgassing contamination.

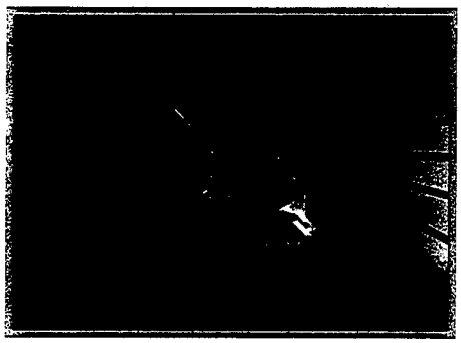
About The Technology

Taylor Devices' 1.12-pound strut uses a hermetic, frictionless damper, with silicone oil as the damping medium. Central to the damper's design is a piston rod submerged in a cylinder of silicone oil. Two relatively stagnant oil cavities within the damper exchange oil levels; when the damper is displaced, oil moves between cavities through a controlled orifice, providing the damping action. The hermetic seal for the oil reservoir stops leakage or outgassing. The silicone degrades slowly and its viscosity changes minimally, even with large temperature fluctuations.

Long-Lasting Laser Diodes Contribute To Commercial Endeavors

While satellite communications are well advanced, the ground segment of the communications system still has bottlenecks. When a signal is transmitted from space to Earth, a series of information links must be made. Each link requires converters, amplifiers, and other devices that match the radio frequency (RF) signals to the digital parts of the chain. These devices also ensure that the signal is strong enough for it to be intelligible for the end user.

The satellite communications system, however, would be much more efficient if the original down-linked signal, in RF format, could be transmitted over longer distances and without having to be converted to a digital signal and then back to an RF signal again. Ortel Corporation (Alhambra, CA) is addressing this problem with fiber optics.



Ortel has pioneered technology using linear fiber optics, which can transmit broadband RF signals. Their proprietary linear lasers modulate light intensity with the RF signal and transmit it through fiber-optic cable. One of the essential components of its system is a BMDO-funded laser diode, durable enough to withstand the high power that communications systems demand. Ortel's success in developing its fiber-optic products has led it to a worldwide fiber-optic market that is expected to triple from the 1994 $5.7 billion estimate.

An essential component of Ortel's system is a BMDO-funded laser diode durable enough to withstand the high power required for satellite communications.

Late last year, Ortel made an initial public offering of 3.8 million shares to increase production. They raised $32 million, resulting in a market capitalization of well over $200 million. The company holds 12 U.S. and 2 foreign patents and has a large customer base in the United States and abroad. Ortel is now expanding its facilities and marketing its product internationally. For example, it sells its products to Norwegian Telecom, Hong Kong Telecom, and Singapore Telecom.

Ortel's 10-gigahertz laser diode, pictured above, is available in the United States and internationally. The company's laser diodes operate in either analog or digital formats and provide high reliability at a relatively low cost.

The company's linear fiber-optic products have similar applications in the cable industry, where they can be used for two-way, interactive, data, voice, and video transmission. These products can support video-on-demand, interactive cable television shows, video game channels, and other entertainment venues.

About The Technology

Laser diodes that operate at wavelengths shorter than 1 micron and at high power are less reliable than their longer wavelength counterparts. These shorter wavelengths and higher powers are especially important for optical interconnects in fast computers and in integrated optoelectronics components for telecommunications. The poor reliability of older laser diode technology results from degradation of the gallium arsenide/aluminum gallium arsenide material induced by optical absorption at the laser output facet. Ortel solved this problem by fabricating diodes with laser facets that are nonabsorbing at the laser output wavelength. These laser diodes operate in either analog or digital formats and provide high power with high reliability at a lower cost.

Ortel also worked on ultralow-threshold laser diodes based on gallium arsenide/indium gallium arsenide ternary alloys for use in the submilliampere and microampere ranges; these ranges are important to produce microelectronics for fast, high computational power computers with very fast data flow rates. Applications include integrated optoelectronics and computer interconnections, avionics, broadband communications networks, cellular and wireless systems, and future supercomputers.

Heat Exchanger Launched On Commercial Satellite

When satellites are launched into the harsh environment of space, their costly and essential onboard electronics need protection from extreme temperatures. Actively pumped radiator and cooling systems have been available for years to address these problems, but they are usually very bulky and prone to mechanical failures.

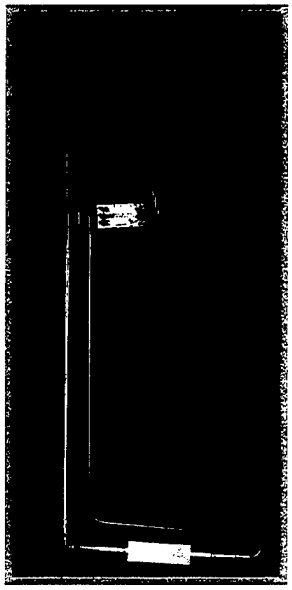
Swales, Inc. (Lanham-Seabrook, MD), has reduced the size and increased the reliability of protective components for temperature control. They have developed a passive technology called the capillary pumped loop, or CPL, that serves as a heat exchanger for critical satellite components. Developed with BMDO funding, the CPL has recently been launched on Final Analysis, Inc.'s FAISAT-1—the first of 26 commercial telecommunications satellites set in space for reading utility meters and tracking commercial vehicles. Swales' CPL is expected to be used in all 26 satellites if its ruggedness is proved.

SWALES' DEVICE WAS LAUNCHED ON FINAL ANALYSIS, INC.'S FAISAT-1—THE FIRST OF 26 COMMERCIAL SATELLITES FOR TRACKING VEHICLES AND READING UTILITY METERS.

Phillips Laboratory sponsored Swales' CPL on the satellite. The satellite was launched in January 1995 and, since mid-February 1995, has collected data for microgravity measurements and interactive data transmission between selected Earth sites and the satellite. All 26 satellites are expected to be launched by the year 2000.

In addition, Swales has provided CPLs and BMDO-funded heat pipes for the service and recovery modules of the COMET spacecraft. COMET will provide a short- and intermediate-term test platform for commercial in-orbit experiments. Motorola plans to use COMET for testing to prepare for the deployment of its IRIDIUM™/℠ satellite network.

While Swales has focused on satellite applications, another company called Dynatherm Corporation (Cockeysville, MD) has been looking at CPLs for terrestrial uses. Working with Goddard Space Flight Center, this company is miniaturizing CPLs and incorporating them into bodywear to protect heavy equipment users from extreme temperatures. The technology can transfer heat from the warmer areas of the body to the cooler areas requiring heat, such as the ears, hands, and feet. The technology can be used in reverse for firefighters and workers in heavy industry facing localized high temperatures. Further into the future, CPLs may be used in solar heating systems, road surface deicing, waste heat recovery, terrestrial electronics, and warmed ski gloves.



Swales' capillary pumped loop, pictured above, was chosen for the FAISAT-1 because of its small size, light weight, tight temperature control, and relatively passive operation.

About The Technology

Swales Thermal Systems (formerly OAO Thermal Systems), under Phillips Laboratory, provided the CPL design for Final Analysis, Inc., in the deployment of FAISAT-1. BMDO funded early development of the CPL for space-based applications as well as other Swales projects through the Brilliant Eyes program. The Air Force has funded two projects through Phillips Laboratory. One was a 60-kelvin phase change material device to control the temperature of cryogenic infrared sensors. The other was a cryogenic flexible heat pipe diode, which thermally couples a cooler to the sensor, protecting the sensor against heat backflow in the event of a cooler failure.

The CPL launched with the FAISAT-1 satellite is intended to last many years and was chosen for its small size, light weight, tight temperature control, and relatively passive operation. This device uses a working fluid to transfer heat via evaporation and condensation. It is a looped pipe made of aluminum or stainless steel, typically filled with ammonia. The CPL is first heated, or "primed." Evaporation of the fluid absorbs the heat; the gas travels via capillary action, and condensation of the evaporant at the cooler end of the device releases the heat. Engineers exploit this process to absorb heat from power-producing components, to transfer the heat to components requiring warmth, and to reject excess heat to space via a radiator. Passive capillary action, which is the adhesion of fluid to the solid walls of the pipe, helps move the working fluid from one end of the device to the other.

New Deposition Method Aims To Speed Communications

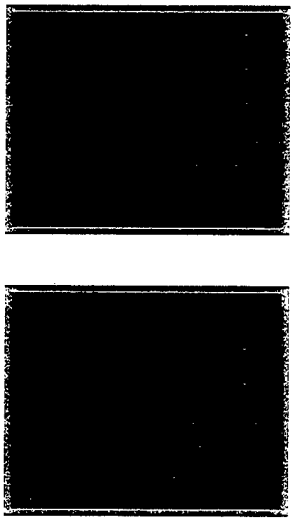
Many developing countries have had trouble establishing telecommunications systems because they lack the infrastructure for wire- or optical-based systems. They may also be challenged by rough topography, which makes establishing infrastructure extremely difficult. Wireless satellite communication can overcome these obstacles because it requires minimal infrastructure and is virtually unaffected by topography. One approach is to use many inexpensive communications satellite "constellations" to communicate between remote locations, rather than an expensive and inflexible satellite in stationary orbit. But to complete this telecommunications picture, new technologies will be needed to link satellites together.

With BMDO funding, Cornell University has developed a process to make semiconductors for economical satellite high-speed data and voice communications.

High-performance semiconductors must be improved for the satellite nodes of a low-cost networked satellite communication system to be linked. BMDO has funded numerous projects that can contribute to such improvements, including work at Cornell University (Ithaca, NY), led by Dr. James Shealy. His group has used BMDO funding to develop a process called flow modulation epitaxy (FME) to create a new gallium arsenide semiconductor material with ideal characteristics for satellite communication devices, enabling high-speed data and voice communications. The Joint Service Electronics Program (Air Force Office for Scientific Research) and the Advanced Research Project Agency's Optoelectronics Technology Center at Cornell have also contributed to this work.

The low-voltage, high-frequency characteristics of semiconductor materials fabricated by Cornell researchers will allow new satellite linkages using handheld communications devices. Other applications are two-way worldwide messaging, emergency and rescue information transmission, stolen vehicle recovery, and personal digital assistants. Semiconductor Equipment Materials International and other senior semiconductor forecasters project that the general market for epitaxial materials will grow annually at 8 to 15 percent through the year 2000.

Dr. Shealy notes that several companies have benefited from BMDO-funded research by employing his students after they graduate. For example, one of his former students now works at Motorola, where he has applied his research at Cornell to make significant contributions to the cellular telephone industry. Another former student has applied the knowledge he gained from BMDO-funded research to visible red laser technology at Xerox.



Pictured above are surface views of Dr. Shealy's heterogeneous crystalline lattice.

About The Technology

Dr. Shealy fabricated the world's shortest period superlattice involving an arsenide-to-phosphide transition. One crystal structure of this type allows high electron mobility, which enables low-voltage operation and high electron saturation velocity; this translates to device speed. The heterostructure, which is based on the III-V alloy gallium arsenide, offers high frequencies, high speed, and low voltages, qualities needed for the next generation of personal communication devices.

Dr. Shealy's use of FME, which required modification of an organometallic vapor phase epitaxy (OMVPE) apparatus, allows smooth interfaces to be created between heterogeneous crystalline lattices. FME involves the use of non-steady state reactant fluxes, but FME can be scaled up to function as an OMVPE method for large-scale production of such heterostructures. In this research, a crystal composed of aluminum gallium indium phosphate on gallium indium arsenide was fabricated. The pseudomorphic structure is ideal for a high electron mobility field-effect transistor (FET). FETs are required to advance communication devices to low-voltage (to 0.9 volt), high-frequency operation. Personal digital assistants slated for future production will require such semiconductors. OMVPE is considered ideal for large-scale production of this semiconductor material.

New Deposition Method Aims To Speed Communications

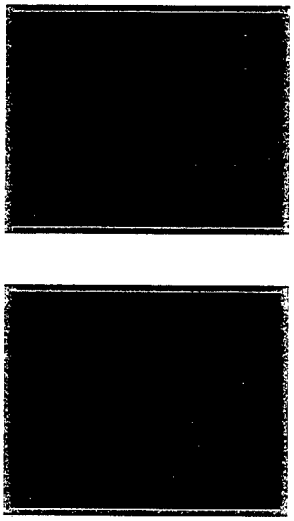
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Planes, trains, and cars—the United States has traditionally been a nation on the go, highly dependent on efficient and reliable transportation. But as the 21st century approaches, people are finding their commutes by automobile longer and more congested, and often downright dangerous, with nearly 40,000 traffic fatalities each year.[1] In fact, the Federal Highway Administration forecasts that the number of vehicles on the road will rise 50 percent by the year 2005 over the 1988 figures, and the typical commuter's delay will rise from 15 minutes to about 1 hour.[2] And we are finding travelers more dependent on air travel to conduct routine business, creating new financial incentives for the airline industry to maintain the performance of its fleets and keep them running on time.

Many types of advanced technologies, such as electronics and materials, can improve the performance and safety of transportation systems. For example, innovative sensors can be used to prevent car collisions. High-temperature microelectronics can improve the performance, fuel consumption, and lifespan of aircraft by monitoring and controlling critical elements of jet engines, such as temperature, pressure, thrust, and fuel flow. And new material processes can make automobile and airplane parts more durable at lower costs. Ultimately, advanced technology will help improve the reliability of transportation systems, eliminate traffic congestion and delays and—most important—save lives.

Today's market. Automobile and aircraft manufacturers see signs that the transportation industry is beginning to grow after leveling off in the early 1990s. In one example, sales of passenger cars and light trucks in the Unites States totaled 15.06 million units in 1994, up 8.4 percent from 1993.[3] In another, jet aircraft makers are expecting $1 trillion in sales over the next 20 years, owing to growing passenger traffic, aging fleets that need replacement, and a return to profitability of the whole airline industry.[4] Technology is even allowing individuals to plan their own road trips right on their home computers, choosing from several options such as fastest, most scenic, or shortest routes. About 750,000 people purchased travel-planning software last year, and this market is growing rapidly. In 1994, sales reached $30 million, up 250 percent from 1993.[5]

Tomorrow's opportunity. BMDO's R&D in materials and advanced sensors has produced many innovations for ballistic missile defense systems. These innovations have been incorporated into new technologies that can help the transportation industry to improve safety, increase equipment performance, reduce congestion, enhance mobility, and minimize environmental damage. The following section describes seven such examples.

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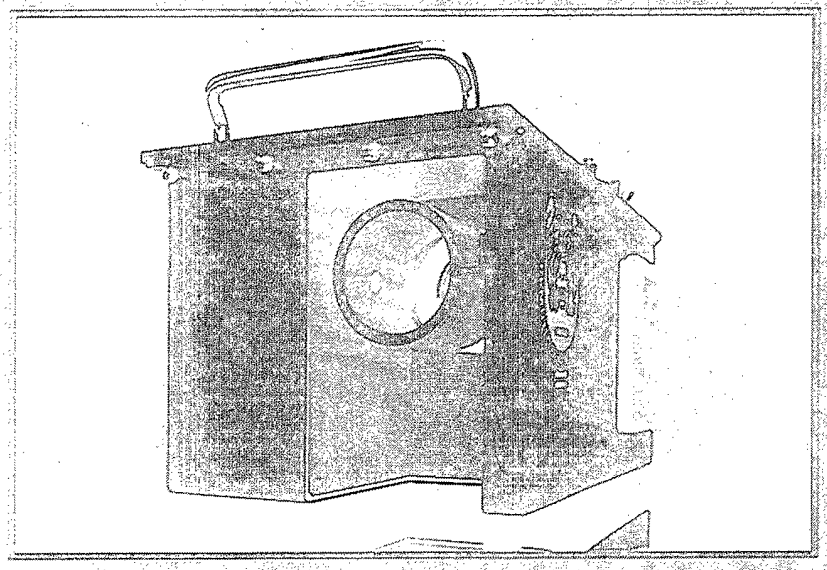
[1] Smart Solutions...S. Taylor; *American City & Country*, September 1994, p. 48.

[2] Smart Cars and Smart Highways...M. Fiseheti; *Photonics Spectra*, November 1994, p. 77.

[3] *Industry Surveys*, Standard and Poor's, April 27, 1995, p. A-96.

[4] Business Bulletin: A Special Background Report on Trends in Industry and Finance...*Wall Street Journal*, June 22, 1995, p. A-1.

[5] Travel Software Offers Info for the Highway...*Wall Street Journal*, May 12, 1995, p. B-11



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TRANSPORTATION

RAD-HARD TECHNOLOGY BREAKS TEMPERATURE BARRIER FOR MICROELECTRONICS



SSEC is supplying HOTronics™ sensors to three jet turbine engine manufacturers for testing in the next-generation control systems of commercial and military jet turbine engines.

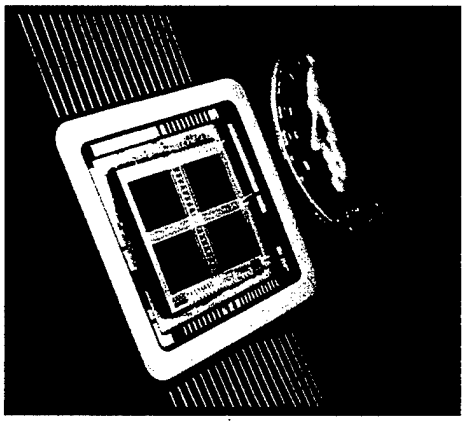
Manufacturers of aircraft engines need to mount sophisticated microelectronics directly on engines to improve control, efficiency, and performance. But current devices cannot bear the heat generated during engine operation. When exposed to temperatures above 125°C for long periods, they become unreliable and eventually fail.

Honeywell, Inc.'s Solid State Electronics Center, or SSEC (Plymouth, MN), has developed a silicon-on-insulator (SOI) technology that allows its HOTronics™ sensor and HTMOS™ electronic products to endure high temperatures. SSEC is supplying HOTronics™ sensors to three manufacturers of jet turbine engines for testing in the next-generation control systems of commercial and military jet turbine engines. The new sensors can reliably monitor critical elements such as temperature, pressure, position, and fuel flow for improved turbine engine control.

HONEYWELL'S HIGH-TEMPERATURE MICROELECTRONICS USE BMDO-FUNDED SILICON-ON-INSULATOR TECHNOLOGY TO WORK BETTER AND LAST LONGER IN HIGH-TEMPERATURE ENVIRONMENTS.

SSEC is also teaming with a major automotive manufacturer to develop a sophisticated V-8 engine management system. HOTronics™ sensors are being tested to measure the position of engine valves and monitor fuel flow. Such functions can help the engine management system reduce the amount of pollutants being emitted.

In addition to engine management, SSEC's high-temperature sensors and electronics have immediate applications in oil field and industrial instrumentation. The devices also may have potential in space, commercial nuclear power, power conversion, and plastics/composites forming applications.



Pictured above is a small silicon-on-insulator CMOS device next to a dime. Honeywell's sensors, based on this technology, can operate at temperatures as high as 225° C—100° C greater than competing devices.

SSEC expects the markets for high-temperature electronics and sensors to grow from $20 million in 1994 to $60 million by the year 2000. It will also target the market for high-temperature automotive sensors operating above 170°C, which is predicted to grow from $5 million to $20 million in the next 5 years.

ABOUT THE TECHNOLOGY

With funding from BMDO, SSEC developed microelectronic device technology to make complementary metal-oxide semiconductor (CMOS)-based microcircuits immune to high levels of radiation by employing SOI materials. SSEC found that, with little or no modification, SOI CMOS technology could also be used to help microelectronics operate at temperatures up to 225°C—100°C greater than competing devices. SOI CMOS technology eliminates the p-n junction of a conventional ion-implanted sensor. This junctionless sensor provides robust fail-safe operation in virtually any type of hostile environment. The electronic components for the sensors are fabricated using Honeywell's high-temperature oxide-isolated process.

SSEC's first product line, HOTronics™, features several high-temperature sensors used for measuring pressure and magnetic fields. The second line, HTMOS™, includes two high-temperature electronic devices—the Quad Operational Amplifier and the Quad Analog Switch—used in analog signal conditioning for sensors and for analog control functions. Additional HTMOS™ devices will be under development through 1996.

New Carbon-Carbon Deposition Process Could Lower Brake Costs



This Boeing 737 uses airplane brakes by B.F. Goodrich. Future brakes, which will be strong, lightweight, and capable of significant thermal conductivity, may be made of a carbon-carbon composite using a process originated by BMDO.

Heat plays a significant role in the wear of materials. It wears the brakes of aircraft and automobiles, and it degrades the materials used for engines and exhaust systems. Therefore, materials that can resist high temperatures, such as carbon-carbon composites, have become increasingly important; unfortunately, these materials are often very costly and time-consuming to make.

Sioux Manufacturing Corporation (Fort Totten, ND) has developed a new carbon-growing manufacturing method that may soon reduce the production costs of such high-temperature composite materials—reductions that may later translate to lower consumer costs. Carbon-carbon materials can be used in everything from airplane and automobile brakes to the circuit boards of high-density electronic equipment.

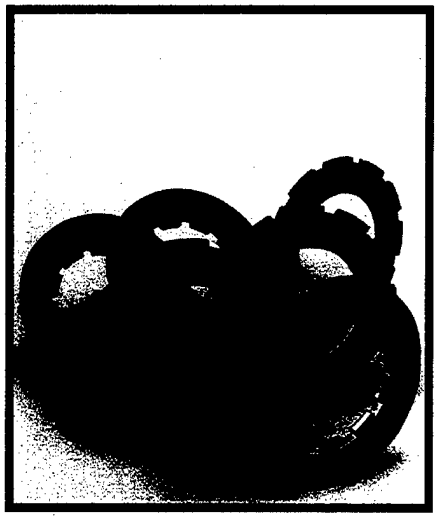
Sioux Manufacturing has recently teamed with B.F. Goodrich to continue work on the composite. B.F. Goodrich plans to integrate Sioux's carbon-growing process into its aircraft brake manufacturing to improve its existing product line.

Sioux Manufacturing has teamed with B.F. Goodrich, which plans to integrate the carbon growing process into its brake manufacturing business.

Carbon-carbon materials processing was first developed for the nose cones of re-entering space vehicles. Through a BMDO SBIR, Sioux Manufacturing has successfully tested a new method for growing the carbon before it is applied to the underlying carbon fibers that together comprise the carbon-carbon composite.

The material can be used as the fins at the ends of the circuit board to carry heat away from electronic components. It could also replace the fiber epoxy currently used as the substrate of circuit boards, as it would be able to transfer heat out of the housing much faster than the conventional material can.

In satellites, the expansion and contraction of materials in the extreme temperatures of space can lead to material failure, such as cracking or bending. The new carbon-carbon material has a very stable coefficient of thermal expansion between the carbon and the fibers, so that satellite components or housings would be better protected from temperature fluctuations.



Pictured above are aircraft brake disks, components that may benefit from Sioux's materials technology.

About The Technology

Carbon-carbon composites consist of carbon fibers surrounded by a matrix of carbon. Sioux Manufacturing's process for making these composites uses a magnetite catalyst, which is a ferrofluid, to increase the decomposition and deposition reaction rate of methane gas. At the end of the process, the methane gas deposits itself as carbon on the preformed fibers. The new technique increases deposition speed by a factor of three and therefore may considerably reduce the cost of producing the composite.

The first experiments with the new process were performed using only laboratory-scale samples. B.F. Goodrich is now working with Sioux Manufacturing to verify that the rate enhancement will carry over to large-scale samples.

Power R&D Improves Materials Processes For Auto Industry

Automobile manufacturers are looking for new ways to quickly produce automotive parts, such as the gears in automotive power trains that meet demanding performance requirements. Traditional manufacturing methods, such as using high-pressure forming and punch presses on blanks, are quick but they leave jagged edges and rough surfaces that require postmachining—a time-consuming process.

One alternative to traditional methods is powder metallurgy, a process in which metal powders are compacted into smooth shapes, eliminating the need for polishing and finishing. Powder metallurgy is used for some components in the automotive industry, but it has not yielded the densities required for very rugged, high-performance components. Such components are still stamped or forged, making them costly to manufacture.

Applying power technology from a BMDO SBIR, IAP Research, Inc. (Dayton, OH), has developed a technique called dynamic magnetic compaction (DMC) that makes powders used in powder metallurgy dense enough to be used for high performance automotive parts. The process both speeds manufacturing and improves the quality of the parts, thereby saving the automotive industry money and time.

> IAP RESEARCH MAY SAVE AUTO MAKERS TIME AND MONEY BY SPEEDING UP THEIR PARTS MANUFACTURING CAPABILITIES.

IAP is leading an $8.4 million cost-shared Advanced Technology Program project awarded by the National Institute for Standards and Technology to further develop DMC. IAP has teamed with General Motors Powertrain Division and Zenith Sintered Metal Products; the team will contribute $4.3 million to the project and is focusing on complex automotive transmission components. IAP plans to produce and sell the electromagnetic parts-making equipment to car parts manufacturers such as its joint venture partner, Zenith Sintered Metal Products, which will then sell parts to General Motors and other major manufacturers.



IAP Research's process has been used to form metal rods, as shown above. Powder is loaded into a copper tube (right) and the compaction process forms the powder into a nearly fully-dense rod (left).

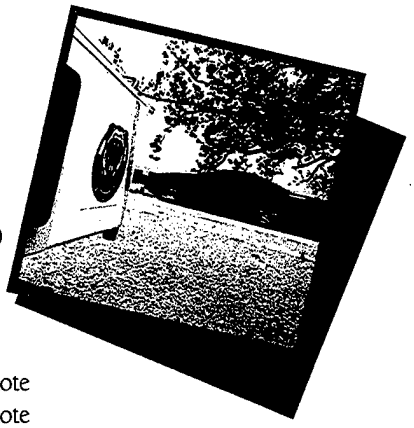
Researchers at IAP believe manufacturers using DMC can make a complete gear, including the teeth, in less than a second. Starting with powdered steel, the process uses high-pressure pulses generated by an electromagnet to compress the powder into a die to make a solid part. The pressures are equivalent to those under a 4,000-pound weight supported on a three penny nail. A second step in the process sinters or "bakes" the part to strengthen it. BMDO originally funded IAP's development of electromagnetic power supplies for rail gun accelerators used in space to destroy enemy missiles. This power technology is central to the compaction technique.

About The Technology

In DMC, high currents are passed through a compactor coil from an electromagnetic power supply system. The metal powder is enclosed in a confining container and placed at the center of the compactor coil. For electrically nonconducting powders, the confining container has to be conductive; for conductive powders, this restriction does not apply. The currents in the compactor coil generate magnetic fields that produce magnetic pressures on the powder, consolidating it. This pressure is directed radially inward on the powder. While conventional techniques apply pressure from the top and the bottom, the IAP method applies pressure from outside in, along the whole length of the part.

Pulsed magnetic forces have two advantages over mechanical forces: (1) very high forces can be generated with a small, low-cost system; (2) the forces can be applied with great precision in time and space. The short pulses permit high repetition rates while offering the possibility of dynamic effects in the powder; that is, the particles compress and heat during the very short pulse, softening and becoming more plastic. This phenomenon may increase the density of the part.

Smog Sensor Detects Pollution-Prone Cars



Smog Dog™ can screen thousands of vehicles per day at no inconvenience to today's busy motorists.

National studies indicate that roughly 20 percent of cars driven today account for about 80 percent of automotive pollution during normal operation.[6] Unfortunately, many of these cars can remain on the road for years because authorities have great difficulty detecting them through the idle test or visual inspection.

State and local governments are investigating new ways to monitor emissions, one of which is remote sensing. Often associated with satellite monitoring of the environment and ground structures, remote sensing can also be used on the ground to detect automobiles with high emissions levels.

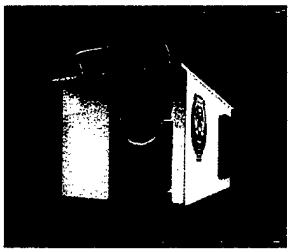
In conjunction with Hughes Aircraft Company, Santa Barbara Research Center, or SBRC (Santa Barbara, CA), is selling an infrared (IR) remote sensing device called Smog Dog™, which "sniffs out" the biggest offenders on roads and highways. The device can automatically measure tailpipe emissions by detecting changes in the intensity of IR "light" beamed across the road. To identify the car, SBRC also offers an Automatic License Plate Reader that can read and record alphanumeric characters from the video image of the license plate.

SMOG DOG™ UNITS BUILT BY SANTA BARBARA RESEARCH CENTER RELY ON INFRARED PHOTODETECTORS TO IDENTIFY CARS AND TRUCKS WITH HIGH EMISSIONS ON AMERICA'S HIGHWAYS.

SBRC recently delivered six Smog Dog™ units to the Arizona Department of Environmental Quality, which began a vehicle emissions testing program in the Phoenix area on May 15, 1995. Owners of vehicles identified as high polluters receive letters requesting voluntary inspection/repair action. If the same vehicle is identified again as a high emitter, a second notice is sent requiring mandatory inspection/repair. SBRC has also sold several units to government agencies in Idaho, Canada, and Australia.

The smog sensor uses a modified device originally developed for BMDO's Heterojunction Interface Trap (HIT) program. HIT was designed to create mercury cadmium telluride IR detectors with reduced bias power requirements and very high sensitivity under low-temperature and low-background-flux conditions. BMDO needed these detectors for ballistic missile surveillance and tracking in the long-wavelength IR region.

In addition, SBRC has used its HIT detectors to create remote sensing instruments for the government. For NASA, SBRC developed several linear sensor arrays such as the Moderate Resolution Imaging Spectroradiometer to provide geophysical, atmospheric, chemical, and biological information on Earth. The company has also developed linear sensors, such as the multispectral thermal imager, for treaty-compliance applications.



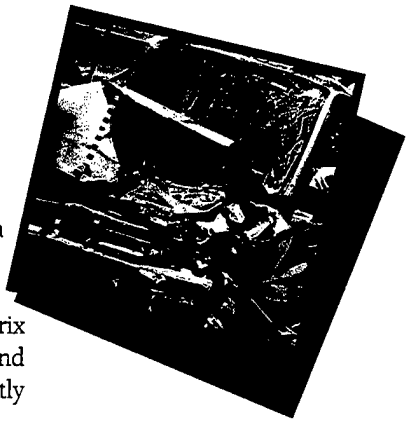
Santa Barbara Research Center's infrared sensor passively measures automotive emissions when cars are being driven at speeds up to 65 miles per hour.

About The Technology

To detect pollution-prone vehicles, the van-mounted IR source on one side of the road directs a beam across the road—usually single-lane ramps to highways—to a sensor on the other side. When a vehicle breaks the beam, Smog Dog™ measures percentage concentrations of its exhaust gases, which include carbon monoxide, carbon dioxide, hydrocarbons, and nitrogen oxides. The IR sensor works by detecting changes in the intensity of the IR beam, which drops when the exhaust gases absorb some wavelengths. Meanwhile, a roadside camera takes a video snapshot of the vehicle. A computer in the van "reads" the exhaust gas concentrations and the letters on the license plate. At the end of the day, the van downloads its data into State computers, which match the information with auto registration records to pick out vehicles whose pollution exceeds allowed levels for their size and model year.

[6] *Remote Sensing Information* (fact Sheet), Arizona Department of Environmental Quality, January 1995.

Sensor Paves Way For Collision Avoidance Capabilities



One of the applications for Picometrix's technology is collision avoidance.

Picometrix, Inc. (Ann Arbor, MI), is using BMDO-funded technology to develop a sensor for a collision avoidance system to detect obstacles in the road that could potentially harm an automobile. Called the SOTA, or sampling optical temporal analyzer, this small solid-state chip could receive signals and send them to a system that redirects the automobile. Picometrix was awarded a $1.4 million research project with the U.S. Army Tank–Automotive Command (TACOM) to continue this work on a picosecond laser radar sensor. The company is currently collaborating with other partners.

Further into the future, this technology could also help increase highway capacity in an intelligent transportation concept called platooning. In this concept, a group of vehicles could travel down a highway inches apart at a fixed speed, reducing travel times and the risk of accidents. The SOTA could help distance the vehicles properly. Picometrix's technology may also be used to optically recognize bar codes on highway signs, allowing this information to be displayed on the driver's dashboard. This capability could eliminate the need for traditional street signs and/or help prevent drivers from missing their turnoffs.

> Through a licensing agreement, Picometrix's photodetectors are now widely available through Newport Corporation.

Operating at least 100 times faster than existing compact sensor technology, the SOTA is a photodetector and a photogate on one chip. It is as sensitive as a conventional photodiode but responds much faster. The SOTA is expected to be on the market by June 1996.

Through a licensing agreement, Picometrix is selling its photodetectors (an intrinsic part of the SOTA) to the scientific community. The devices are widely available through Newport Corporation—one of the largest distributors of laboratory laser equipment. Newport offers two Picometrix-developed products, the PX-D7 and the PX-D14. With a response time of 7 picoseconds, the PX-D7 is the fastest photodetector available commercially, costing less than $6,000. It is easier to use and can gather light 100 times more efficiently than competing technologies. The PX-D14 is a slower version of the device with a response time of 14 picoseconds and costs less than $4,000.

Spinning off his own company, Steve Williamson, principal investigator for this BMD research at the University of Michigan's Ultrafast Science Optical Laboratory, formed Picometrix roughly 4 years ago to productize his findings. With some manufacturing capabilities on a subsystem level, Picometrix continues to work closely with the university in its research. Picometrix has since received related BMDO SBIR funding.



The PX-D7, shown above, has a response time of 7 picoseconds and is the fastest photodetector available commercially.

About The Technology

As a result of BMDO-funded research at the University of Michigan, Picometrix demonstrated a photoconductive 1-picosecond photodetector, which can function as a detector at low optical intensities or as a switch at high optical intensities. As sensitive as a silicon photodiode, this fast version uses gallium arsenide as the active semiconductor. The arsenic-rich properties of the growth process ultimately make the photodetector highly resistive and responsive and contribute to its short carrier lifetime.

Using the technology's dual functionality, researchers have integrated the photodetector on the same chip as a similar laser-activated photogate. The photodetector can perform two functions, allowing 1-picosecond optical signals to be detected and processed without the ultrafast signal ever leaving the sensor chip. Together, the 1-picosecond photodetector and photogate form the world's fastest, most compact, ultrasensitive picosecond optical waveform analyzer. The output from this device is an electrical signal that can be measured using conventional electronics. It operates jitter-free and has an anticipated signal sensitivity as low as 1 picowatt and dynamic range exceeding 10^6.

Intelligent Software To Benefit Travel Industry

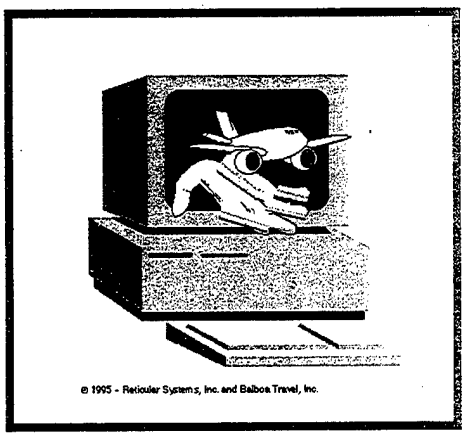
To cut costs, the airline industry is reducing commissions it pays to travel agencies. Such reductions, which will ultimately help make plane tickets cheaper, have forced travel agencies to get leaner, cutting services that flyers take for granted. For example, travel agencies may have to start charging more to pay for keeping records of frequent flier information, seating preferences, and other travel needs.

But while the travel agencies and airlines are cutting back, corporations are continuing to demand better travel management services. In addition to services such as reservations and ticketing, firms on the go need policy consulting, monitoring of adherence to travel policy, cost reporting, and information services and analysis.

Reticular Systems, Inc. (San Diego, CA), is developing a family of travel-related intelligent software that could significantly improve the way reservations are made and increase the efficiency of travel agencies. The products are designed to serve the major customer communities: travel agencies, corporate travel managers and travel arrangers, and mobile travelers. The core software will allow developers to enhance their application software products by adding reservation-making capabilities. The products could include commercial desktop productivity software, integrated office suites, on-line services, and CD-ROMs.

RETICULAR SYSTEMS IS BUILDING INTELLIGENT SOFTWARE PRODUCTS THAT ARE SMART ENOUGH TO BOOK AND CHANGE TRAVELER RESERVATIONS ON THE FLY.

To commercialize this intelligent software, Reticular Systems and a nationally ranked travel agency called Balboa Travel, Inc. (San Diego, CA), have formed a strategic alliance and are creating a new company. The new company, provisionally called Madison, is looking for equity funding from investors to finance continuing development, marketing, sales, and product support for the software. The products will be developed using AgentBuilder™, a software tool kit for constructing intelligent agent software. AgentBuilder™ has been developed using another tool called IntellAgent™. Both tools resulted from a feasibility study funded by BMDO.



Intelligent software could significantly improve the way travel reservations are made and increase the efficiency of travel agencies.

Under a NASA proposal, Reticular Systems hopes to build an intelligent electronic notebook for astronauts using the IntellAgent™. The notebook will also feature recent advances in voice recognition, speech synthesis, natural language processing, user modeling, and object-oriented databases.

In addition to creating software to automate travel reservations, early versions of AgentBuilder™ are being used to build products to retrieve information intelligently from large databases and for other information processing tasks. They are also serving as intelligent adversaries in computer-based games.

About The Technology

Intelligent agents allow computer users who do not know how different databases work to efficiently extract information from a whole network of them. The agents are therefore useful in any line of work where large, diverse data sets are needed to make complex decisions.

Unlike a simple search routine, an intelligent agent must carry out many complex functions. For example, an intelligent agent used in situation assessment must be able to sense the environment, assess the environment, develop plans for problem solution, execute the plan steps, and learn as the system interacts with the environment. It also must tolerate missing or incorrect information and reason in a way that meets rapidly changing demands.

New Sensor For Antilock Braking Systems To Improve Safety And Reliability

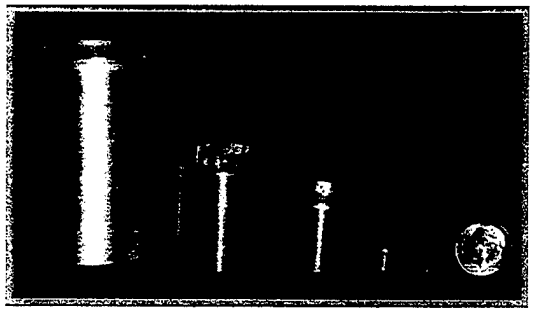
Once a car slides on ice or loose gravel, it is often too late for the driver to regain control. No matter how quickly the driver slams on the brakes or turns the steering wheel, the car is likely to spin out of control. If this happens, the driver faces one of the most hazardous forms of collisions—the side impact.

Applied Technology Associates, or ATA (Albuquerque, NM), is using magnetohydrodynamic (MHD) technology to improve the safety and performance of braking, steering, and handling systems. Using this technology, ATA has developed the MHD effect rate gyroscope (MERG) to measure the steady rotation in cars, planes, and satellites. By signaling that the car has begun to swerve right or left uncontrollably, the new sensor will help the antilock braking system's computer to engage front and rear brakes sooner and more effectively. This procedure will re-orient the car so that its front faces oncoming traffic or objects. Such positioning can saves lives, since front impacts are the least hazardous form of collisions.

Applied Technology Associates' technology will result in advanced sensing products for next-generation braking, steering, and ride stabilization systems in vehicles.

MERG sensors are an attractive option for antilock braking systems because they can potentially be smaller, lighter, less expensive, and more energy efficient than current technology. The estimated cost of the compact sensor is less than $25 when the device is manufactured in high volumes. At this price, automotive manufacturers can afford to improve antilock braking systems, expected to be used in all U.S. automobiles by the year 2000.

The MERG sensor can also be applied in vehicle navigation systems that receive signals from satellites. The Army will soon be using MERG sensors to test a new land navigation system in its high-mobility multipurpose wheeled vehicle, which was heavily used during Desert Storm. MERG sensors may also be useful in areas such as attitude measurement and control for aircraft/aerospace, robotics, rotational equipment control, and machine diagnostics.



ATA has developed a family of angular rate sensors, shown above, which are based on the magnetohydrodynamic principle.

About The Technology

Magnetohydrodynamic sensors, which use the interaction between a conductive fluid and a magnetic field to measure angular motion, operate with great precision in diverse environments. These solid-state, hermetically sealed sensors range from shock detection devices that are as small as a dime and weigh just 7 grams to nanoradian measurement devices that resemble a small juice can. The sensors have been tested at forces 1,200 times that of gravity, and analytical predictions have shown they could withstand forces 50,000 times that of gravity.

ATA has developed two general classes of MHD sensors: passive and active. The passive sensors, which measure shock, vibration, and other time-varying motions, are sold commercially for applications in crash dummy testing and vehicle dynamic testing; they are also being evaluated for traction control systems such as antilock braking systems. The active rate sensors, including the MERG sensor, function like a gyroscope; they measure the steady motion of cars, planes, and satellites. ATA developed the basic technology underlying all of these sensors in a BMDO project to measure angular vibration in a space-based laser system.

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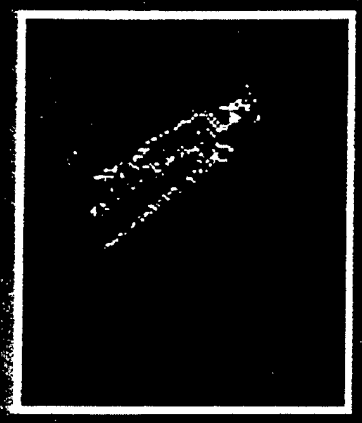
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The Technology Applications program looks forward to the continued success of these and other BMDO-funded companies, laboratories, and universities in providing innovative products that will help maintain the United States' leadership in the international economic arena.

If you are looking for more information on innovative technologies or the Technology Applications program, you can write, call, fax, or e-mail us at:

The BMDO Technology Applications Office
c/o National Technology Transfer Center
Washington Operations
2121 Eisenhower Avenue, Suite 400
Alexandria, Virginia 22314

Telephone (703) 518-8800 ext. 500
Facsimile (703) 518-8986
Internet leslie@nttc.edu



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